A COMPARATIVE TEST
OF
INTEGRATING WATTMETERS

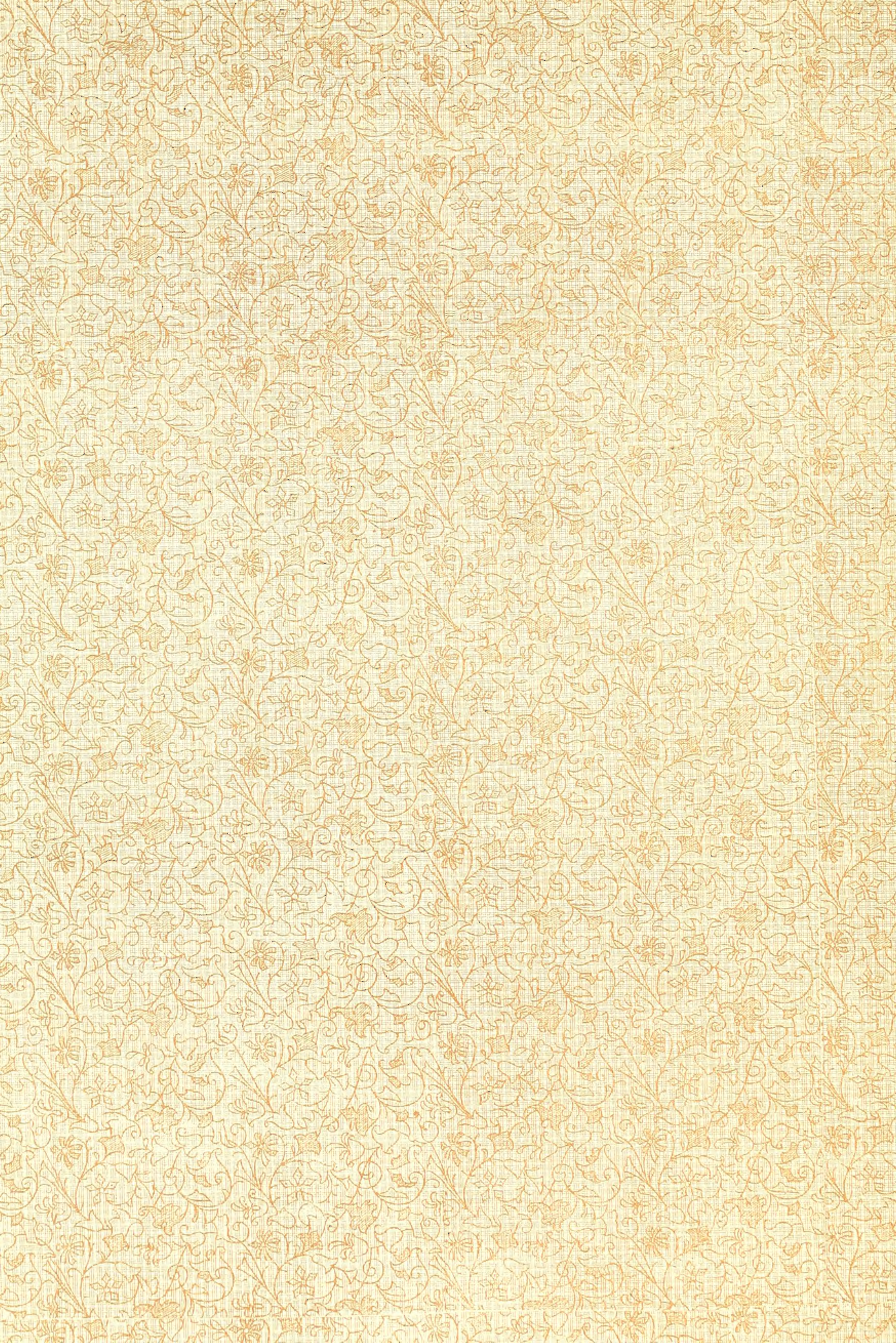
BY

M. J. ANDERSON and A. B. CORNWELL

Armour Institute of Technology

1908

537.7
An 2



AT 99
Anderson, M. J.
Comparative test of
integrating wattmeters

For Use In Library Only

13
26

A COMPARATIVE TEST
OF
INTEGRATING WATTMETERS

A THESIS

PRESENTED BY

MARION J. ANDERSON
AND
AUGUSTUS B. CORNWELL

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

ELECTRICAL ENGINEERING

June 1st, 1908

ILLINOIS INSTITUTE OF TECHNOLOGY
PAUL V. GALVIN LIBRARY
35 WEST 33RD STREET
CHICAGO, IL 60616

Approved
A. A. Radtke
Prof. of Elec. Eng.

L. C. Monin
Dean of the Cultural Studies

H. M. Raymond
Dean of Eng. Studies

A Comparative Test of Integrating Wattmeters.

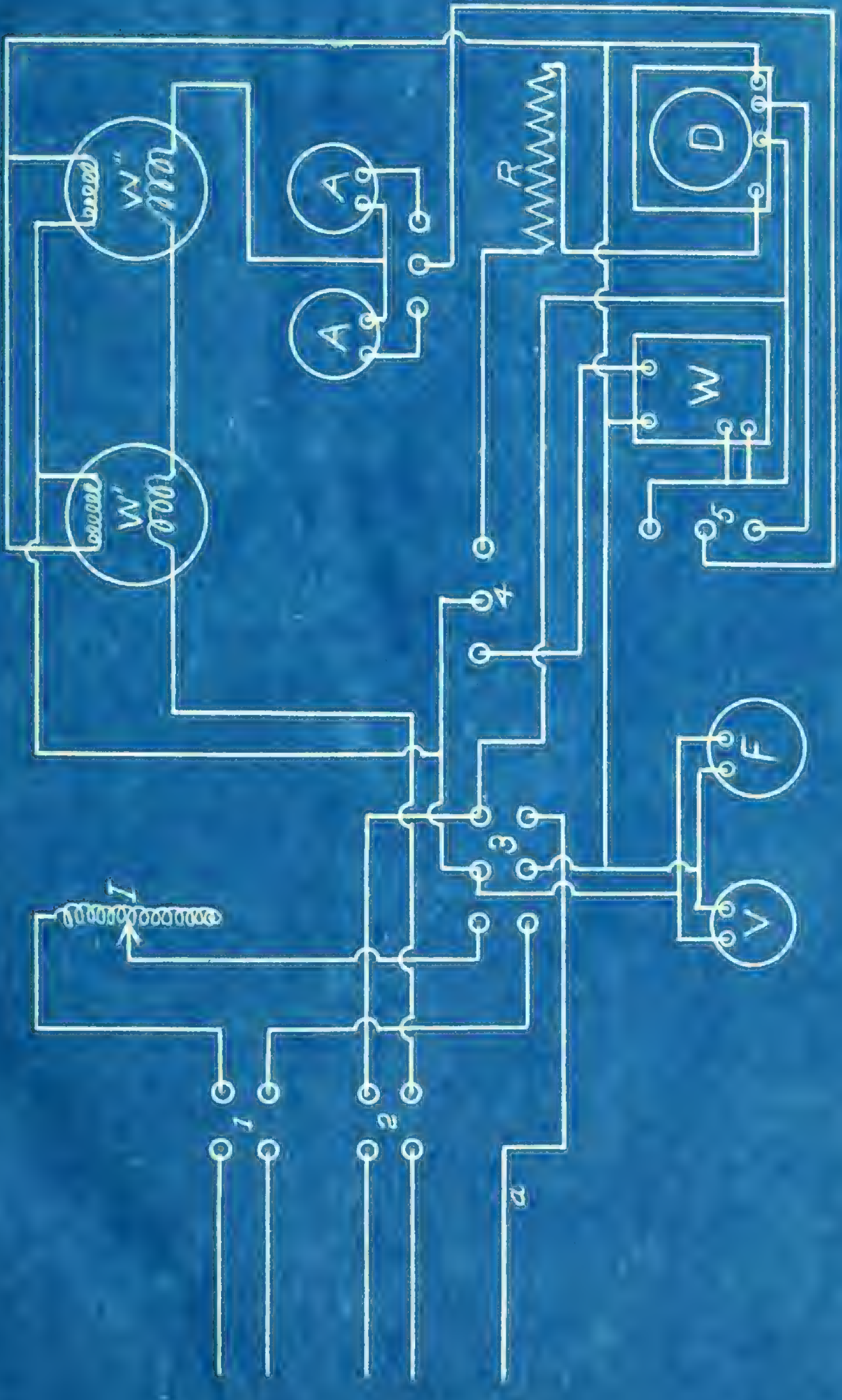
The object of this thesis is to determine the per cent accuracy of the meters tested when operated on loads varying from no load to 150 % load with voltages varying from 10 % below to 10 % above normal voltage, with different frequencies, and with different power factors; also to determine the phase relation of the series and pressure fluxes of each meter.

The following apparatus was used for this test;-

1- Weston Voltmeter. A.C. & D.C. (0-120).
2- Thomson Ammeters. A.C. (0-5) & (0-25).
1- Weston Wattmeter. (10 ampere).
3- Frequency Meters. (25-60-125 cycles)
1- Dynamometer.
1- Stop Watch.
1- Counter.
1- Variable Inductance.
Lamp Bank.
Two Phase Alternator. (60 cycles).
Single Phase Alternators. (25-60-125 cycles)
Storage Battery.

20764

SCHEME of CONNECTIONS
for
Integrating Wattmeter Test



ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

On the preceding blue print is shown a scheme of the connections used. The leads from switch 1 are connected directly to one phase of a two phase alternator. The leads from switch 2 connect to the series posts of the lamp bank; the lower lead "a" connects directly to one side of the second phase and the upper lead of switch 2 connects to the other side of the second phase, thus giving the pressure of the second phase on the right hand posts of switch 3 when switch 2 is closed. V and F are the voltmeter and the frequency meter. W is the Weston wattmeter. D is the dynamometer. R is a non-inductive resistance in series with the pressure coil of the dynamometer. By means of the double throw switches 4 and 5 either the wattmeter or the dynamometer may be connected in the circuit. A and A represent the high and low reading ammeters, either of which may be connected to the line by means of the double throw switch 6. W' and W" are the watt hour meters under test. I is a variable inductance connected in series in one of the leads of the upper phase, for the purpose of adjusting the phase relation of the currents in these two phases. By throwing switch 3 to the right all pressure apparatus is connected to the lower phase, and by throwing it to the left all pressure apparatus is connected to the upper phase.

In order to obtain good results in this test it

was necessary that the load, the voltage and the frequency be maintained constant during the run. This was accomplished by operating the motors, to which the generators were attached, from a 60 cell storage battery. The field rheostats of both motor and generator were placed by the testing table to give convenient control of the frequency and the voltage.

The method of procedure was as follows;- First all instruments to be used were calibrated by comparing their readings with those of the standard instruments of the laboratory of Armour Institute of Technology. The voltmeter used was made for A.C. and D.C. and it was calibrated by comparing its readings directly with those of the standard D.C. voltmeter. In making this comparison two readings were made in determining each point of the calibration, one with the current in one direction and the other with the current in the reverse direction, the average being taken for the true reading, thus eliminating any effect of stray magnetic fields. The dynamometer, to be used in the determination of the flux phase relation, was calibrated as a wattmeter by comparing its readings with the standard volt-amperes. For the calibration of the A.C. ammeters it was necessary to first calibrate a dynamometer as an ammeter by comparing its readings with those of the standard ammeter, direct current being used for this calibration, and then to calibrate the ammeters by

comparing their readings with those of the dynamometer, alternating current being used in this second calibration. The Weston wattmeter was calibrated by comparing its readings with the product of those of the calibrated ammeter and voltmeter.

When an integrating meter was placed on the testing board and connections made as shown in the above scheme, the meter was first tested to ascertain if it were running at correct speed with full load current, unity power factor, normal frequency, and normal voltage. The number of revolutions made by the disc in about two minutes was counted. This number multiplied by the disc constant and divided by the time required to make this number of revolutions gives the watts recorded, which corresponds to the watts given by the Weston wattmeter if the integrating meter is running at the correct speed. In case the meter ran too fast or too slow under these normal conditions the position of the damping magnet was adjusted until the proper speed was obtained. In this manner all the meters tested were adjusted to record within 2% of the true watts when operating under normal conditions at full load.

In cases where the disc constant was not given the recording train was removed and the ratio of the revolutions of the disc to the revolutions of the first dial was determined by counting the number of revolutions

made by an intermediate gear, usually the one that meshed with the gear on the spindle, to one revolution of the first dial, and then determining the ratio between this gear and the one on the spindle. From these the disc constant can be determined directly.

After an accurate adjustment had been obtained a run was made with normal frequency, normal voltage and unity power factor, about seven or eight readings being taken as the load was varied from no load to 150 % load. Then like runs were made with approximately 10 % above and 10 % below normal voltage.

The meter was next tested for accuracy with different power factors. The variable inductance I was disconnected from the upper phase, as shown in the scheme, and connected in series with the load on the lower phase, being placed in the lower lead of switch 2, which is the load side of the meters. With the I inductance in this particular lead we were able to vary the power factor without changing the voltage impressed upon the instruments. Readings were taken for the determination of the per cent accuracy with normal voltage, normal frequency, constant full load current and power factors varying from unity to about .500.

A test was next made to determine the phase relation of the series and pressure fluxes. The connections were as shown in the scheme, switches 1 and 2 being closed, switch 3 being thrown to the left and made by an intermediate gear, usually the one that meshed with the gear on the spindle, to one revolution of the first dial, and then determining the ratio between this gear and the one on the spindle. From these the disc constant can be determined directly.

After an accurate adjustment had been obtained a run was made with normal frequency, normal voltage and unity power factor, about seven or eight readings being taken as the load was varied from no load to 150 % load. Then like runs were made with approximately 10 % above and 10 % below normal voltage.

The motor was next tested for accuracy with different power factors. The variable inductance I was disconnected from the upper phase, as shown in the scheme, and connected in series with the load on the lower phase, being placed in the lower lead of switch 2, which is the load side of the meters. With the inductance in this particular lead we were able to vary the power factor without changing the voltage impressed upon the instruments. Readings were taken for the determination of the per cent accuracy with normal voltage, normal frequency, constant full load current and power factors varying from unity to about .500.

A test was next made to determine the phase relation of the series and pressure fluxes. The connections were as shown in the scheme, switches 1 and 2 being closed, switch 3 being thrown to the left and switches 4 and 5 being thrown so that the Weston wattmeter was connected in the circuit. With the switches in these positions all pressure circuits are connected to one phase and all series circuits are connected to the other phase of the two phase alternator. The load was adjusted until the desired current was obtained and this current was then maintained constant thru-out this particular test. The inductance I was adjusted until the phase difference between the currents in the two circuits was approximately 90 degrees, as indicated by the very low reading of the Weston wattmeter. and by the very slow movement of the disc of the integrating meter. Switches 4 and 5 were now thrown so as to connect the dynamometer in the circuit. A reading was made on the dynamometer and the speed at which the disc was rotating was determined by noting, with a stop watch, the time required for a point on the disc to pass between two noted points on the stationary portion of the meter, as for example across the width of the damping magnet. It was not necessary to know the exact speed of the disc in revolutions per minute but simply to know the speed relative to some fixed part of the meter in order that the disc could be given the exact same speed when the flux phase relation was readjusted. Two more readings were made on the dynamometer with this same speed and direction of

rotation of the disc, the inductance I being readjusted previous to each reading, and the watts corresponding to the average of these first three readings was taken as the true watts for this phase relation of the series and pressure currents. The true watts divided by the apparent watts gives the cosine of the angle between these currents. The position of the core of the inductance was now changed until the disc was rotating in the opposite direction with a speed equal to that at which it was revolving in the first direction. Three readings were taken on the dynamometer for this direction of rotation of the disc and the watts corresponding to the average of these readings was taken as the true watts for this phase relation of the series and pressure currents. These true watts divided by the apparent watts gives the cosine of the angle between these currents for the second position of the core of the inductance coil. If it was necessary to reverse the connections of the dynamometer to get a positive reading when the inductance was adjusted so as to change the direction of rotation of the disc then one of the readings was considered positive and the other negative, indicating that one of the angles was less than 90 degrees and the other was greater than 90 degrees. In the meters of the induction type the phase angle from a quadrature relation of the series and pressure fluxes rotation of the disc, the inductance I being readjusted previous to each reading, and the watts corresponding to the average of these first three readings were taken as the true watts for this phase relation of the series and pressure currents. The true watts divided by the apparent watts gives the cosine of the angle between these currents. The position of the core of the inductance was now changed until the disc was rotating in the opposite direction with a speed equal to that at which it was revolving in the first direction. Three readings were taken on the dynamometer for this direction of rotation of the disc and the watts corresponding to the average of these readings was taken as the true watts for this phase relation of the series and pressure currents. These true watts divided by the apparent watts gives the cosine of the angle between these currents for the second position of the core of the inductance coil. If it was necessary to reverse the connections of the dynamometer to get positive reading when the inductance was adjusted so as to change the direction of rotation of the disc then one of the readings was considered positive and the other negative, indicating that one of the angles was less than 90 degrees and the other was greater than 90 degrees. In the meters of the induction type the phase angle than a quadrature relation of the series and pressure fluxes when used with a single phase current, is equal to the average of the phase angles from quadrature as obtained from these two sets of readings. In the meters not of the induction type the phase angle between the series and pressure fluxes is equal to the average of the phase angles from quadrature obtained from these two sets of readings.

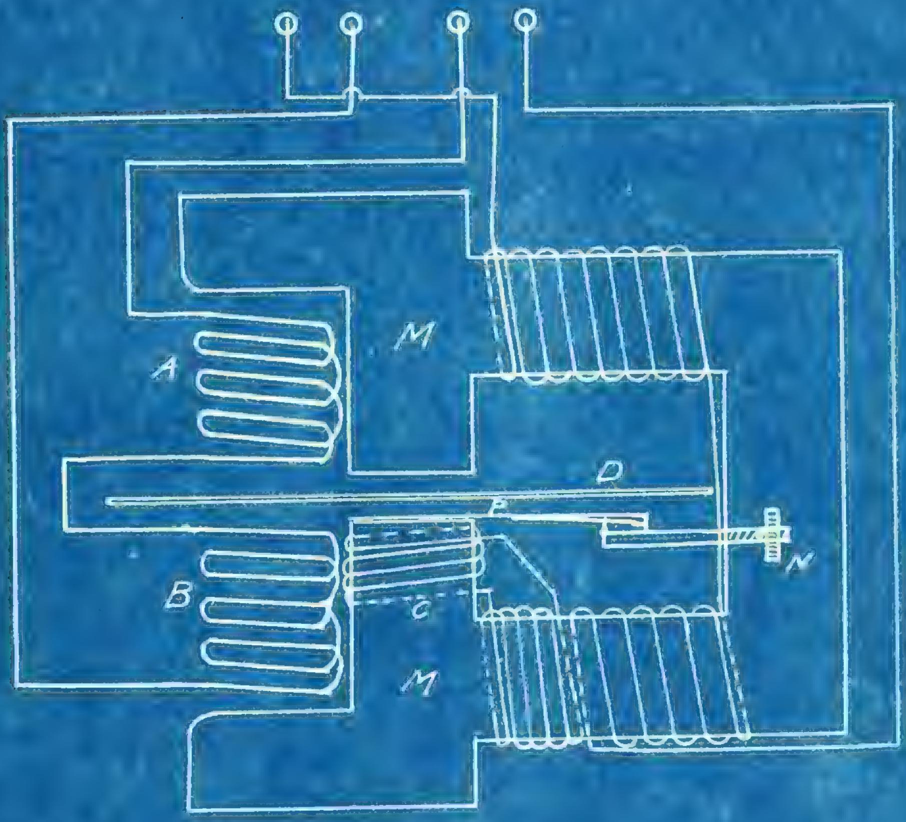
There is a small error in this method of determining the flux phase relation due to the fact that the meters are compensated for friction and this compensation aids the movement of the disc in a forward direction and resists movement in a backward direction. With high torque meters this error will be small and that it is small in this case is shown by the fact that the per cent accuracy of these meters with different power factors as calculated from this flux phase determination agrees very closely with that determined directly by the use of these different power factors as described above.

Tests were next made with frequencies of 25 and 120 cycles, the connections being first made to the 25 cycle alternator. Adjustments were made for the change of frequency if such adjustments were required and the meter was tested for correct speed with normal voltage, unity power factor and full load current and was adjusted to run at correct speed if such adjustment was required. An accuracy test was made with normal voltage and 25 cycles with loads varying from no load

to 150 % load. Similiarly, the apparatus was connected to a 120 cycle circuit and, after all necessary adjustments had been made, the meter was tested for accuracy with normal voltage and 120 cycles thru-out the same range of loads.

Diagram of
The Fort Wayne Integrating Wattmeter

Type W No 252944.



ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

The Fort Wayne Integrating Wattmeter.

Type W. No.252944.

Volts 110. Amperes 10. Cycles 60.

The Fort Wayne watt hour meter is of the induction type. An outline of the meter with circuit diagram is given on the preceding blue print. The series circuit consists of the two coils A and B, one being just above the disc and the other just below it. The pressure circuit consists of the two coils P and P' wound on the yoke of the laminated magnet M, The moving system consists of a light shaft carrying the disc D which rotates between the poles of the laminated magnet M and between the poles of the damping magnet. Speed adjustment is obtained by changing the position of the copper bracket P by means of the knurled nut N. On one leg of the laminated magnet M is wound a small coil C, the object of which is to increase the lag of the pressure flux behind its E.M.F., thus aiding in the production of the quadrature relation between the series and pressure fluxes. The phase relation of the E.M.F. and currents of the different circuits of this meter may be best explained by reference to the following vector diagrams, the first figure being for a non-inductive load and the second one for an inductive load.

Let E represent the impressed E.M.F., and I the current in the series coil in phase with the E.M.F.

Fig. 1.

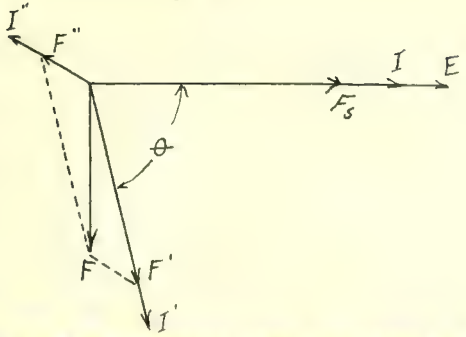
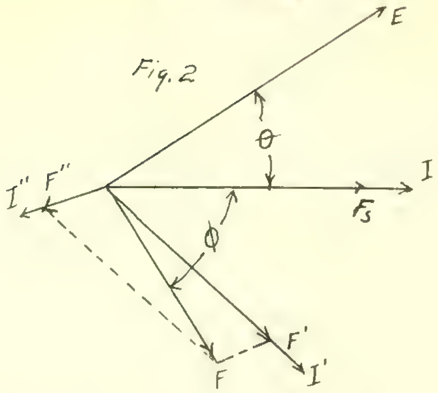


Fig. 2



I' is the pressure current which, because of the self inductance of the pressure circuit, lags by an angle which is a little less than 90° behind the impressed E.M.F. There will be induced in the auxiliary coil C an E.M.F. which will lag 90° behind the pressure flux which produces it. This E.M.F. will cause a current to flow in the coil C which will lag slightly behind its E.M.F. because of the self inductance of the coil. The current in the coil C is represented by the vector I". The flux F" due to the current I" is in phase with I", and the flux F' due to the current I' is in phase with I'. By properly adjusting the resistance of the auxiliary coil C the value of the flux F" may be made such that the resultant of F' and F" will be practically in quadrature with the series flux. The torque upon the disc is proportional to the product of the two fluxes and the sine of the angle between them, hence it is proportional to the product of the impressed E.M.F. and the current in the series coil when the load is non-inductive. If the load is inductive and the current lags by an angle θ behind the impressed E.M.F., the

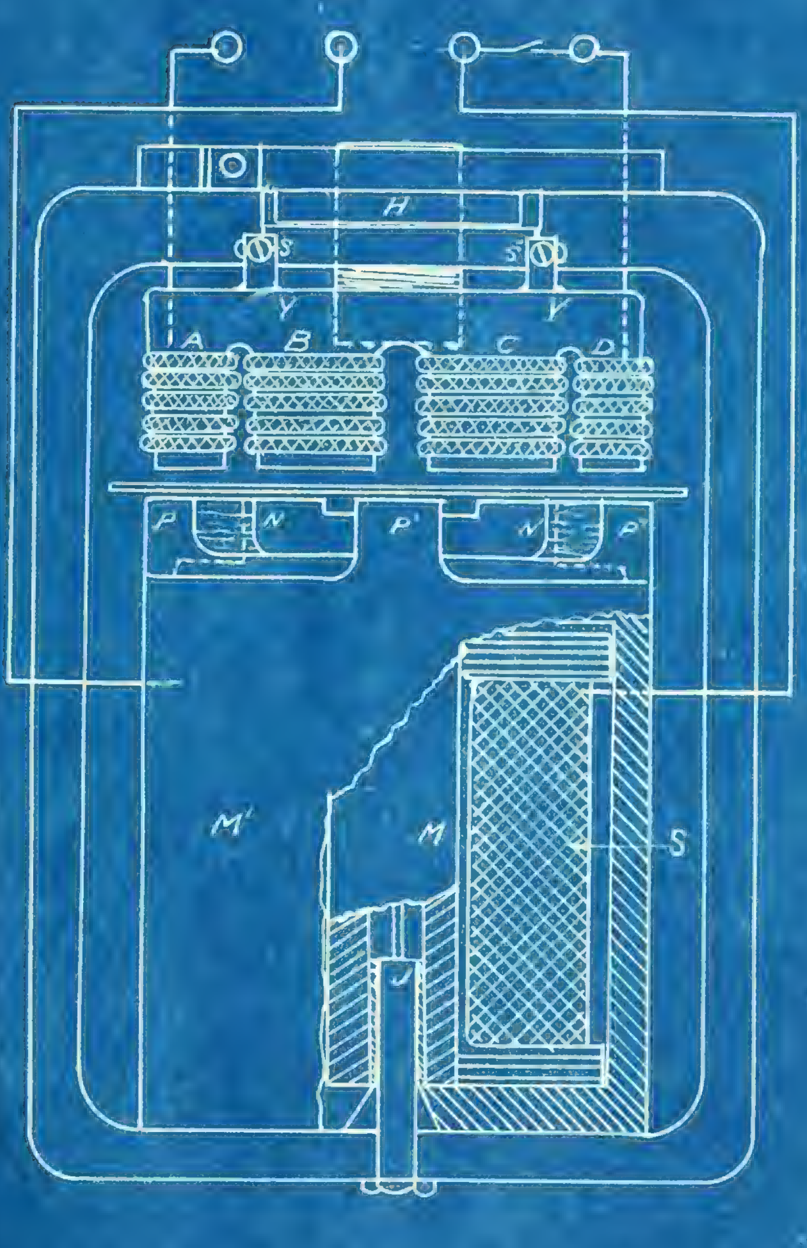
torque will be proportional to the product of the E.M.F. and the series current and the sine of the angle between the series and pressure fluxes, or the sine of the angle Ø as given in the second vector diagram. The sine of the angle between these fluxes is equal to the cosine of 90° degrees minus this angle which is equal to the cosine of the angle of lag of the series current if the meter is correctly adjusted for a quadrature relation between the series and pressure fluxes with a non-inductive load. Hence the torque is proportional to the true power for all loads when the meter is properly adjusted as described above.

The results of the test for the determination of the flux phase relation show the angle between the series and pressure fluxesto be 91° 15.25'. This inaccurate adjustment of the meter for quadrature will make an error of 4 % with a power factor of .500, as shown by the data calculated from this flux phase determination. The error as determined experimentally with a power factor of .508 was about 4.5 %. This meter gives practically the same results with normal voltage and with 10 % high and 10 % low voltage. With a load of one ampere the meter is about 18 % slow. With loads from 5 amperes to 15 amperes this meter gave good results. The Fort Wayne meter now on the market can not be judged by these results as the type K instead of the type W is now manufactured by the Fort Wayne company.

THE FERRANTI INTEGRATING WATTMETER

No. 222322

DIAGRAM OF CIRCUITS.



ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

The Ferranti Integrating Wattmeter.

No.222322. Volts 110. Amperes 10. Cycles 60.

The Ferranti watt hour meter is of the induction type. A general outline of this meter with circuit diagram and sectional view of the pressure coil and magnet is shown on the preceding blue print. This meter is an English make and differs considerably in appearance and construction from the American make of induction meters. It is small and very compact. The series circuit of this meter consists of four small coils, A, B, C, and D, wound on poles formed by slotting the iron yoke Y. The shunt circuit consists of a single coil, S, wound in the form of a bobbin on the tubular core M, and which is surrounded by the semi-cylindrical magnet M', an extension of the core M. The magnet M' has three inwardly projecting poles P, P', and P", and the core M has two poles N, and N' which project radially between the poles P, P', and P", as shown on the blue print. These projecting poles of the shunt magnet are directly under the slots between the poles of the series magnet. The revolving element consists of an aluminum disc mounted on a light vertical spindle which rests on a jewel bearing J. The disc rotates in the air gap between the poles of the pressure and series magnets, and between the poles of the permanent magnet which is mounted in the back of the meter. The reaction of the field, due to the eddy currents induced

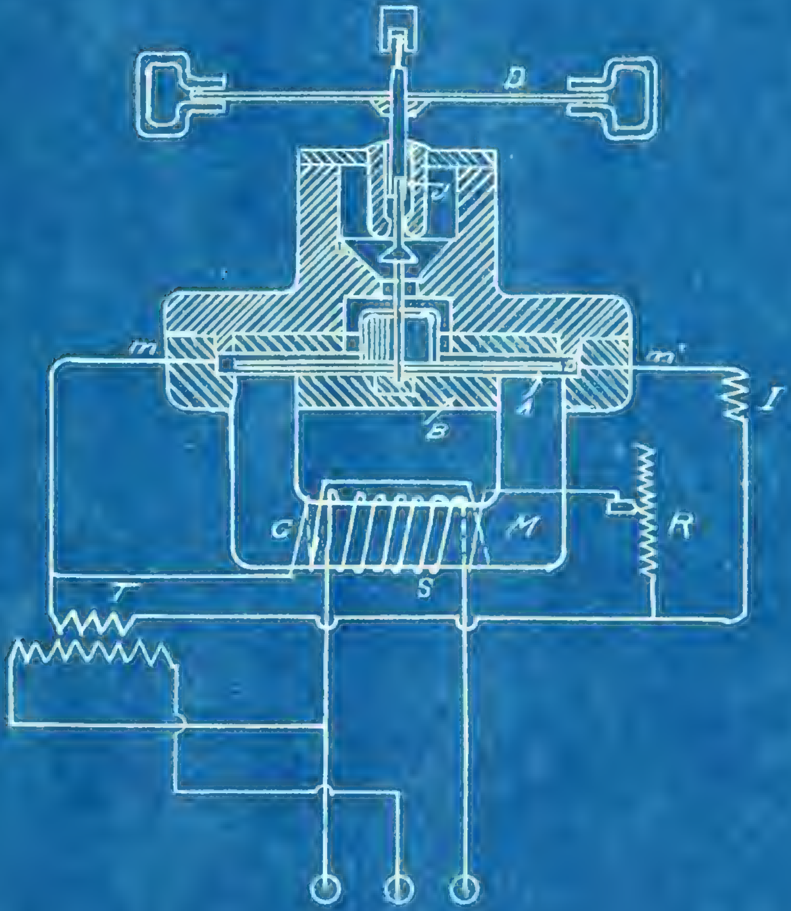
in the disc by the pressure flux, upon the series flux gives to the disc a torque which is proportional to the product of the series flux and the pressure flux, and hence to the true watts. Friction compensation on light loads is effected by turning the series coils about the axis of rotation of the disc by means of the screws S' and S". If the series magnet be displaced in one direction the disc will tend to revolve in the opposite direction and vice versa. The speed adjustment is obtained by raising or lowering the series magnets by turning the nut H. This varies the length of the air gap and hence varies the strength of the series field. When running at correct speed with full load the disc makes 40 revolutions per minute.

The results of the test for the determination of the flux phase relation show the angle between the series and pressure fluxes to be 91° 1.5'. This variation of 1° 1.5' from quadrature will make an error of 3% when the meter is operated on a power factor of .500, as shown by the data calculated from this flux phase determination. The per cent accuracy as determined by these tests is practically the same for normal voltage and for 10% high and low voltage. With a current of one ampere the meter is 15% slow. This meter gave very good results with 25 cycles, but the per cent accuracy obtained for this run can be considered only relatively as no adjustment was made when the meter was placed on the 25 cycle circuit.

Diagram of

The Sangamo Integrating Wattmeter

Type E^{w} No. 66151.



ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

The Sangamo Integrating Wattmeter.

Type E. No.66151.

Volts 110. Amperes 10. Frequency any.

This Sangamo meter is of the mercury type. On the preceding blue print is given a partial vertical section together with an outline of the meter. The moving system consists of a light shaft carrying two discs, D and D'. The upper disc, D, rotates between the poles of two permanent magnets as shown in the upper part of the diagram. The lower disc D', is enclosed in the chamber A which is filled with mercury. The shaft and the discs are buoyed up by the mercury and the upper end of the shaft bears against a jewel bearing J. The two poles of the series magnet M project thru the casing of the mercury chamber and are close to the under side of the disc D'. The series circuit consists of the single coil C wound on the laminated magnet M. T is a small, low potential, step-down transformer, the primary of which consists of a large number of turns of fine wire and is connected directly to the pressure posts of the meter. The secondary winding consists of only a few and in this case of only two turns of heavy wire. The small inductance coil I and the mercury chamber A connected in series constitute the main circuit of the secondary of this transformer. The secondary E.M.F. of this transformer is small but the secondary current is large because the inductance and resistance

of the circuit are exceedingly small. This large secondary current enters one side of the mercury chamber A, flows across the disc D' and leaves at the opposite side of the mercury chamber. In passing across the disc this current flows past the poles of the series magnet M and the reaction between the series flux and the flux due to the secondary current produces the necessary torque. Friction compensation is obtained by means of the small coil C, which is connected thru the variable resistance R to the secondary terminals of the transformer T.

The phase relation of the various currents may be best explained by reference to the following vector diagrams. The first diagram disregards any lag of the currents or fluxes due to the effect of the coils and the iron in the circuits of the meter. The second diagram takes this into consideration. The magnetizing components of the currents in the transformer are so small that they are neglected in both cases.

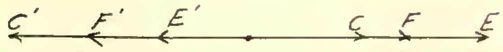


Fig. 1

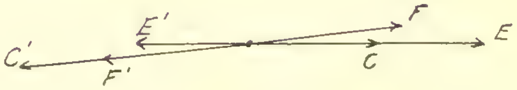


Fig. 2

Let E represent the E.M.F. impressed upon the primary of the potential transformer, and E' the secondary E.M.F. of this transformer. Let C be the current in the series

coil for a non-inductive load. Neglecting any effect due to inductance and hysteresis, the current in the series coil and the flux due to it will be in phase with the impressed E.M.F. Since the secondary circuit of the transformer is non-inductive, neglecting the effect of the inductance coil I for the first vector diagram, the secondary current C' will be in phase with its E.M.F., or 180 degrees out of phase with the series current. By making proper connections to the secondary terminals of the transformer, the pressure current vector C' may be considered to be in phase with the series current. The torque produced in the disc will, therefore, be proportional to the product of the pressure current and the series flux, which is proportional to the true watts.

The second vector diagram takes into consideration the fact that the series flux lags slightly behind the current due to the hysteretic effect of the iron core of the series magnet. In this diagram the vectors E, E', and C represent the same quantities as in the first diagram. F represents the series flux lagging slightly behind the series current due to the hysteresis in the series magnet. The small inductance coil I, see blue print, gives a slight lag to the pressure current bringing it into phase opposition with the series flux. We now have practically the same conditions

as in the preceding case, the pressure current being in phase with the series flux when proper connections are made. The torque will, therefore, as in the first case, be proportional to the true watts.

The results obtained in the determination of the flux phase relation show the angle between the pressure current and the series to be 53'. This will make an error of 2.7 % with a power factor of .500. The error as determined experimentally with a power factor of .514 was between 2 % and 3 %. This meter gives nearly the same results with normal voltage and with 10 % high and 10 % low voltage, except with large overload. The per cent error with a current of 1.5 amperes is about 5 %. With 150 % load the greatest accuracy was obtained with the lowest voltage. With 10 % low voltage the meter is practically correct at 150% load, while with normal voltage there is an error about 3.5 %, and with 10 % high voltage there is an error of about 6.5 % with this same load. Taken as a whole the percent accuracy of this meter is very good. It will operate successfully with 120 cycles but will not operate on 25 cycles. The per cent accuracy on 120 cycles is not as good as on 60 cycles.

The Sangamo Integrating Wattmeter.

Type F. No.76671.

Volts 110. Amperes 5. Frequency, any.

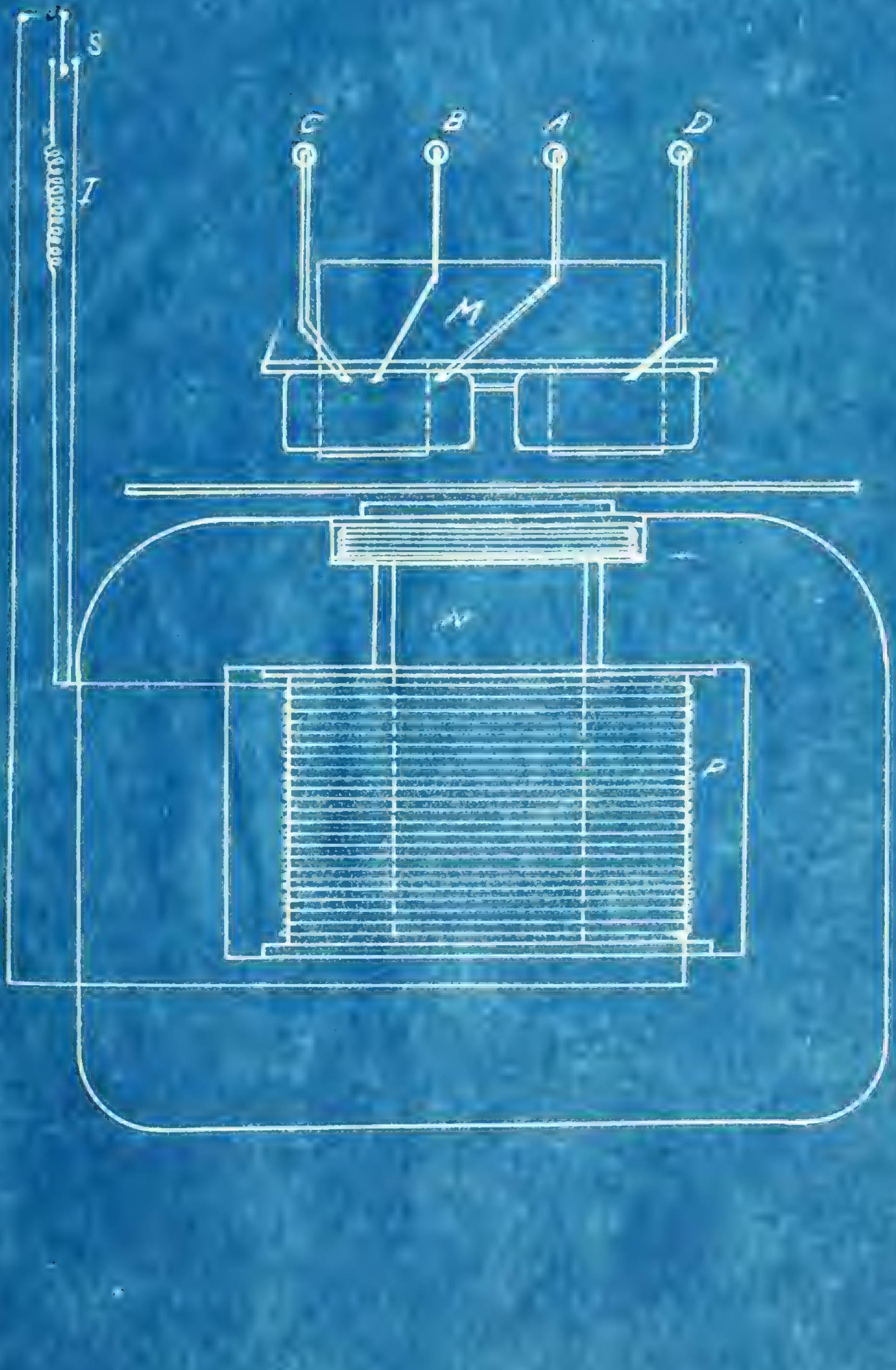
The type F Sangamo meter is very similar, in general construction, to the type E Sangamo meter but it it an improvement over the type E meter. The type F meter will be described with reference to the blue print given with the type E meter. In the type F meter the series coil S is wound in two parts, one part being on each leg of the laminated magnet M. The bottom casing of the mercury chamber is made of an alloy having a high resistance instead of the fibre used in the type E meter. The poles of the magnet M are close to the under side of this casing and hence close to the disc D'. The transformer T of the type F meter has a greater number of turns and a better magnetic circuit than that of the type E meter, hence the quadrature component of the primary current which is very small in the type E meter, as compared to the power component, is made still smaller in the type F meter. The disc D' is stamped in the form of a cart wheel giving a slightly different path to the current flowing across it than in the type E meter which has a plain disc. The vector diagram given with the type E meter applies equally well to the type F meter.

The results of the determination of the flux

phase relation show the angle between the series flux and the pressure current to be 1° 33'. This phase difference will make an error of 4.5 % with a power factor of .500. The error as determined experimentally with a power factor of .570 is 3.4 %. As this error is positive the experimental error should be less than the calculated because friction tends to decrease the error. The type F meter gives practically the same results with normal voltage and with 10 % high and 10 % low voltage. With a load of 1.1 amperes the error obtained was about 9 %. As the load is increased the per cent accuracy rises quickly to approximately 100 % and remains within the allowable 2 % error up to 150 % load.

This meter is independent of the frequency. Run # 7, with normal voltage and a frequency of 120 cycles, was made immediately after run # 6, with normal voltage and a frequency of 25 cycles, no adjustment whatever being required for this change of frequency. The per cent accuracy obtained with 120 cycles is almost identical with that obtained with 25 cycles. In each case the meter was about 10 % slow with a load of 1.1 amperes and was practically correct on larger loads up to 50 % over load.

Diagram of
The General Electric Integrating Wattmeter
No. 1506514



ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

The General Electric Watt Hour Meter.

No. 1506564.

Volts 110.   Amperes 1 - 10 - 20.   Cycles 25 - 60.

This meter is known as the Thomson high torque induction test meter. An outline of the meter together with the circuit diagram is given on the preceding blue print. This meter is designed particularly for testing purposes and in order to obtain a good per cent accuracy with a wide range of load it is constructed with three separate current coils, one for 1 ampere, one for 10 amperes, and one for 20 amperes. ith the use of these three coils we may reasonably get a good per cent accuracy on all loads from, say, .1 ampere to as high as 30 amperes. These coils have one common terminal D, see blue print, and three individual terminals, A, B, and C. They are wound on the two poles of the laminated magnet M. The pressure coil P is wound in the form of a bobbin on the laminated magnet N. The moving system consists of a light shaft carrying a large aluminum disc which rotates in the air gap between the poles of the series and pressure magnets and between the poles of damping magnets. The reaction between the series field and the field of the eddy currents induced in the disc by the pressure flux produces the required torque. The large diameter of the disc aids in producing the high torque. In order to make the meter suitable for both

60 and 25 cycles it is provided with a small inductance coil I which may be connected in series in the pressure circuit by means of the switch S, which is operated by a button at the top of the meter, when it is desired to operate the meter with 25 cycles.

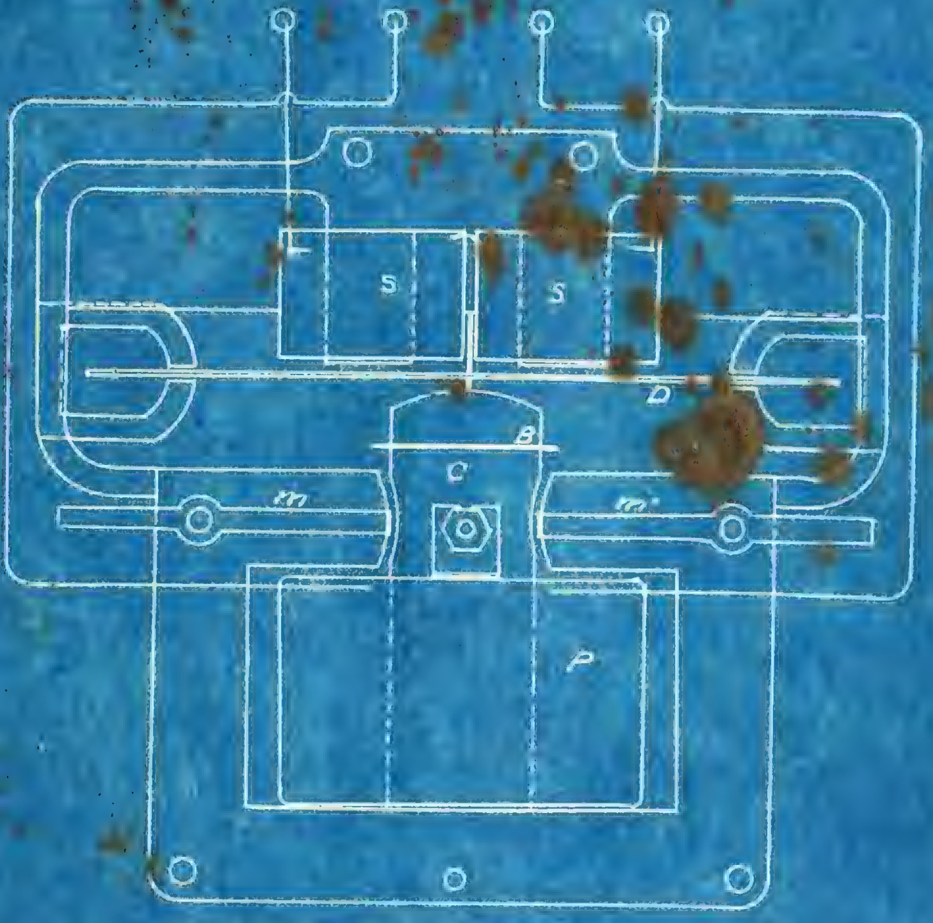
The per cent accuracy of this meter was determined for the ten ampere coil only. The results of the determination of the phase relation of the series and pressure fluxes show the angle between them to be 90° 48.5'. This phase angle from quadrature will make an error of 2.4 % with a power factor of .5, as shown by the data giving the per cent accuracy as calculated from this flux phase determination. The error determined experimentally with a power factor of .536 was 5 %. The large error obtained experimentally is due partly to the fact that, as the error is negative, all frictional effects tend to increase it; also the load under which the experimental error was determined was 50 % of that under which the calculated error was determined. The difference in the per cent accuracy of the meter between full load and 50 % load with normal conditions is approximately 2 % which accounts largely for the difference between the calculated and experimental error with the low power factor. Practically the same results were obtained with this meter with normal voltage and with 10 % high and 10 % low voltage. From 50 % load up to 150 % load the accuracy is within

the allowable 2 % error. With a current of one ampere in the ten ampere coil the meter is approximately 15 % slow. This load, however, is within the range of the one ampere coil with which a negligible error could be obtained. The greatest low load error given with the ten ampere coil with loads beyond the range of the one ampere coil is approximately 10 %. The results obtained with 25 cycles are practically the same as the 60 cycle results.

Diagram of

The Westinghouse Integrating Wattmeter

Type C [illegible] No. 68/372



ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

The Westinghouse Watt Hour Meter.

Type C. No. 681372.

Volts 110. Amperes 15. Cycles 60.

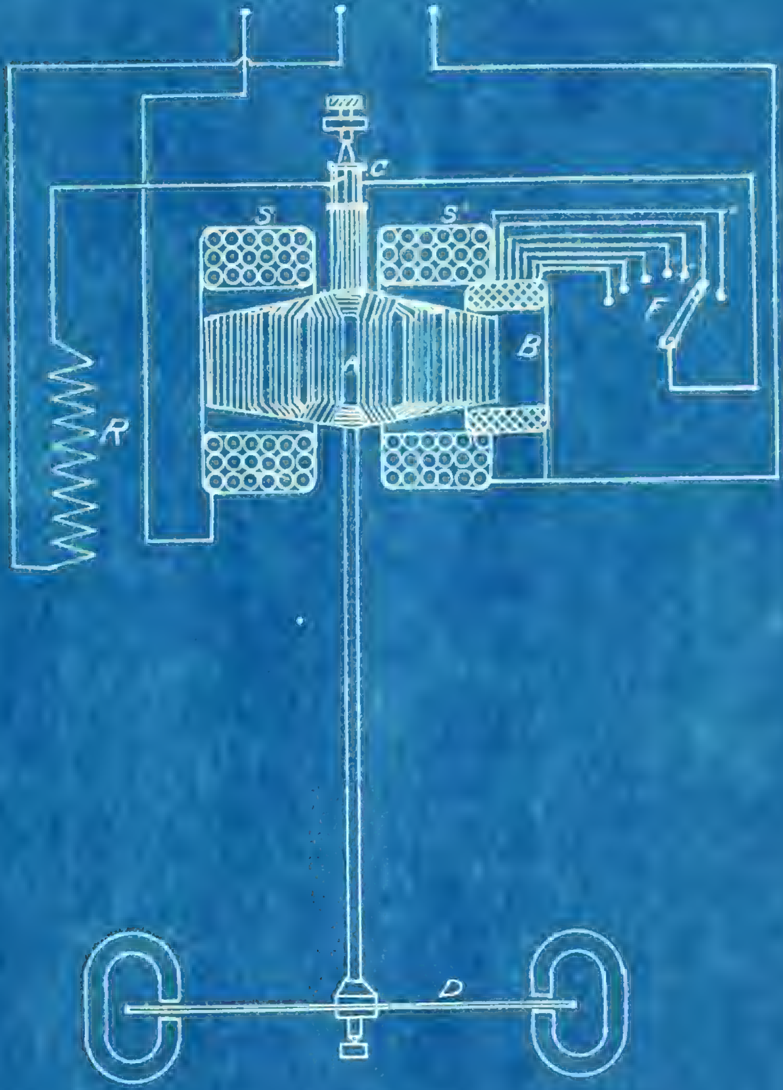
This Westinghouse meter is of the induction type. The blue print given on the preceding sheet shows an outline of this meter with the circuit diagram. The rotating element consists of a light shaft carrying an aluminum disc which rotates between the poles of the series and pressure magnets and between the poles of the damping magnets. On the blue print D represents the disc. P is the pressure coil and S is the series coil. The copper bracket, B, surrounds the laminated pole, C, and furnishes means of adjustment for different frequencies. If the circuit of this bracket is opened the meter will be adjusted for 125 cycles, if this circuit is closed the meter will be adjusted for 60 cycles. The small brackets shown on the outer poles at m and m' provide for friction compensation. The adjustment for friction is obtained by first opening the series circuit, then raising these brackets, m and m' until the meter just starts on the pressure current only, and then lowering the brackets until the disc just stops. With this position of these brackets the torque due to the pressure current alone will not make the meter creep but is nearly sufficient to compensate for all moving friction. The moving system is supported on a highly polished steel ball between two cup-shaped jewels.

The results of the test for the determination of the phase relation of the series and pressure fluxes of this meter show that they are only 34' from quadrature, and that the angle between the fluxes is 90° 34'. This small angle from quadrature will make the meter run less than 2 % slow with a power factor as low as .500, as shown by the data calculated from this flux phase relation. This meter gives practically the same per cent accuracy with normal voltage and with 10 % high or 10 % low voltage, and also with normal voltage and either 25 or 120 cycles. The principal error found was the slowness of the meter on small loads. This meter is new and previous to this test had not been operated since leaving the factory. It was labeled by the manufacturers to be correct within 2 % - or - from 2 % of full load to 50 % overload. When first placed on the testing board it was found that the meter was correct within 2 % at full load and hence no adjustment was given it. The error of this meter under normal conditions with a load of one ampere, or 20 % of full load, was found to be about 25 %. The data shows that there is no decrease in the per cent accuracy of the meter up to 50 % overload, hence we would say that much better results could be obtained thru-out the entire range of the meter if the adjustments were made so that the meter would register correctly, or perhaps one or two per cent fast at about 75 % of full load.

Diagram of

The Duncan Integrating Wattmeter

No. 61666



ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

The Duncan Integrating Wattmeter.

No. 61666. Volts 110. Amperes 10.

This Duncan integrating wattmeter is an alternating current commutator meter. An outline of the meter with the circuit diagram is given on the preceding blue print. The moving system consists of a light shaft carrying the damping disc D, a coreless armature A, and the commutator C. The shaft is supported by a hardened steel point resting on a cup-shaped jewel. S and S' are the series coils. R is a resistance coil, containing no iron, connected in series with the armature. B is the compensating coil, the object of which is to give to the armature sufficient torque to counteract the effect of friction. By means of the small lever and contact points shown at F the number of active turns of this compensating coil can be varied. The flux due to the series coils is practically in phase with that of the armature, hence the meter should be correct on both non-inductive and inductive loads.

The results of the test for the determination of the phase relation of the series and pressure fluxes show the angle between them to be 59'. This will make an error of about 3 % with a power factor of .500, as shown by the data calculated from this flux phase determination. The error as determined experimentally with a power factor of .517 was 3.5 %. This meter gives practically the same results with normal voltage

and with 10 % high and 10 % low voltage. The per cent accuracy is practically the same for both 60 cycles and 25 cycles, there being no decrease in the accuracy up to 150 % load. For 120 cycles the accuracy curve reaches a maximum at about 80 % load and decreases on over load. With 10 % load the meter is about 20 % slow on all frequencies.

The Duncan Integrating Wattmeter.

No. 74520. Volts 110. Amperes 10.

This Duncan meter is a direct current meter. In appearance and construction it is practically the same as the Duncan alternating current commutator meter described above, except that all parts are heavier in the direct current meter that in the alternating current meter. The blue print given with the Duncan meter No. 61666 showing the outline and circuit diagram of that meter applies equally to the Duncan meter No. 74520. In the direct current meter the resistance coil R is enclosed in the back of the meter, being wound in several sections on a thin board. The description given with the Duncan meter No.61666 applies to this meter also.

This meter was tested with alternating current only and the following is a brief summary of the results obtained. The results of the test for the determination of the flux phase relation show the angle between the series and pressure fluxes to be 23.5'. This will make an error of only 1.1 % in the percent accuracy of the meter with a power factor of .500. The error as determined experimentally with a power factor of .517 was about 1 %. A large per cent error was given by this meter on light load, this being 30 % with a load of 1.55 amperes at normal voltage. There is no decrease in the per cent accuracy of the meter up to

The Duncan Integrating Wattmeter.

No. 74520. Volts 110. Amperes 10.

This Duncan meter is a direct current meter. In appearance and construction it is practically the same as the Duncan Alternating current commutator meter described above, except that all parts are heavier in the direct current meter that in the alternating current meter. The blue print given with the Duncan meter No. 61566 showing the outline and circuit diagram of that meter applies equally to the Duncan meter No. 74520. In the direct current meter the resistance coil R is enclosed in the back of the meter, being wound in several sections on a thin board. The description given with the Duncan meter No. 61566 applies to this meter also.

This meter was tested with alternating current only and the following is a brief summary of the results obtained. The results of the test for the determination of the flux phase relation show the angle between the series and pressure fluxes to be 88.5'. This will make an error of only 1.1 % in the percent accuracy of the meter with a power factor of .50. The error as determined experimentally with a power factor of .517 was about 1 %. A large per cent error was given by this meter on light load, this being 30 % with a load of 1.55 amperes at normal voltage. There is no decrease in the per cent accuracy of the meter up to

150 % load. Since the inductance of the circuits of this meter is very small it will be practically independent of the frequency. The results obtained with 25 cycles are practically the same as those obtained with 60 cycles.

Calibration Data for Weston Voltmeter # 5091.

True Volts.	Voltmeter Reading.
90	89.90
95	94.95
97.5	97.5
100	100.0
102	102.05
104	104.1
106	106.0
108	107.9
110	109.8
112	111.85
114	113.75
116	115.75
118	117.85
120	119.80

Calibration Data for Queen & Co's. Dynamometer # 11.

Volts.	Amperes.	True Watts.	Dynamometer Reading.
50	.1	5	2
"	.2	10	5
"	.3	15	7.75
"	.4	20	10.75
"	.5	25	13.75
"	.6	30	16.75
"	.7	35	19.50
"	.8	40	22.50
"	.9	45	25.50
"	1.0	50	28.50
"	1.2	60	34.00
"	1.4	70	39.50
"	1.6	80	45.50
"	2.0	100	57.00
"	2.4	120	68.00
"	2.8	140	79.50
"	3.2	160	90.75
"	3.6	180	102.75
"	4.0	200	111.25
"	4.4	220	125.00
"	4.8	240	136.50
"	5.2	260	147.75

Calibration Data for Thomson A.C.Ammeter # 144085.

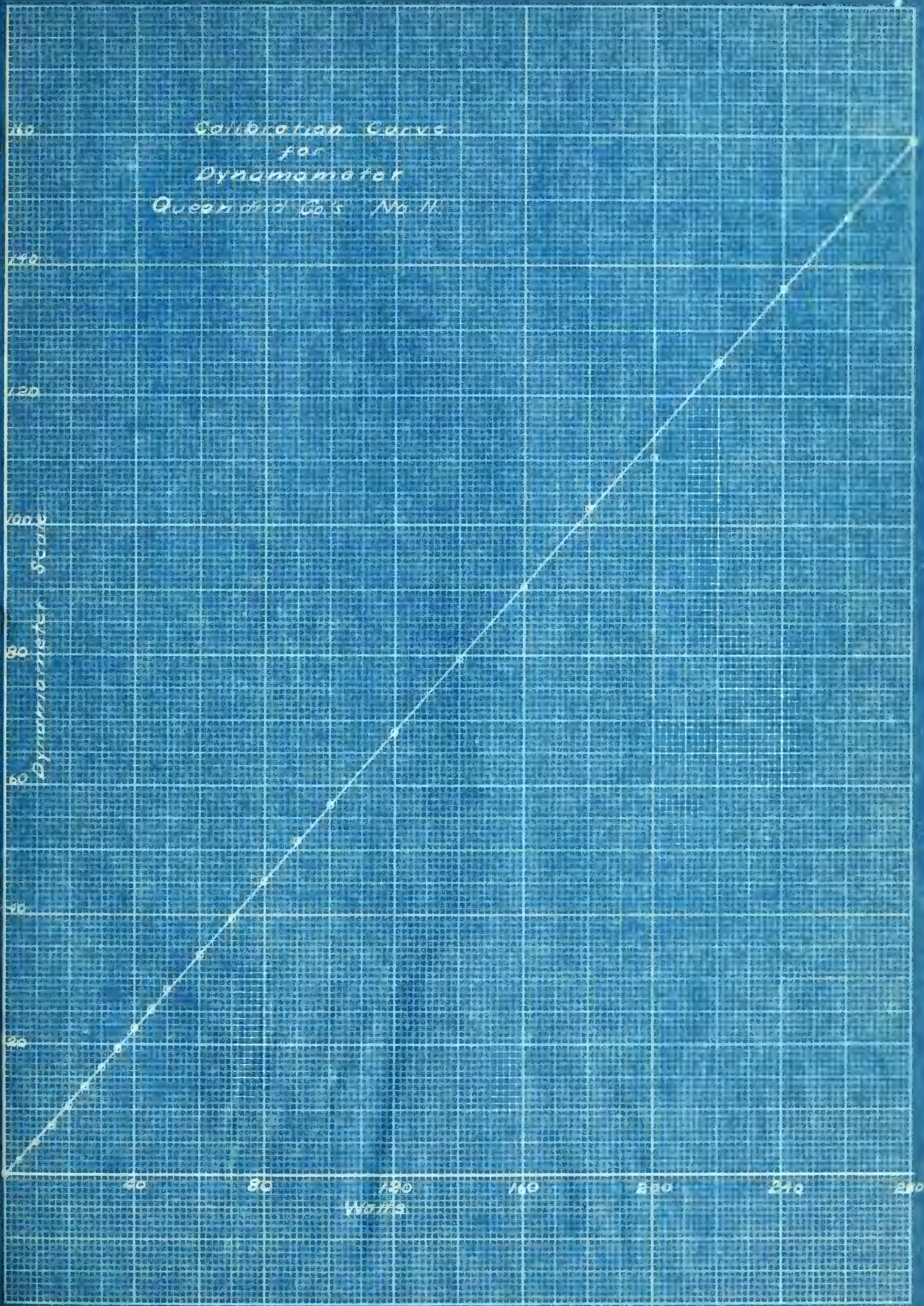
Dynamometer Reading	True Amperes.	Ammeter Reading.
2.	1.0	.90
4.	1.65	1.44
6.	2.08	1.895
9	2.60	2.38
12.5	3.10	2.97
16.	3.55	3.45
20.5	4.03	3.91
25.	4.45	4.31
30.	4.90	4.74

Calibration Data for Thomson A.C.Ammeter # 82511.

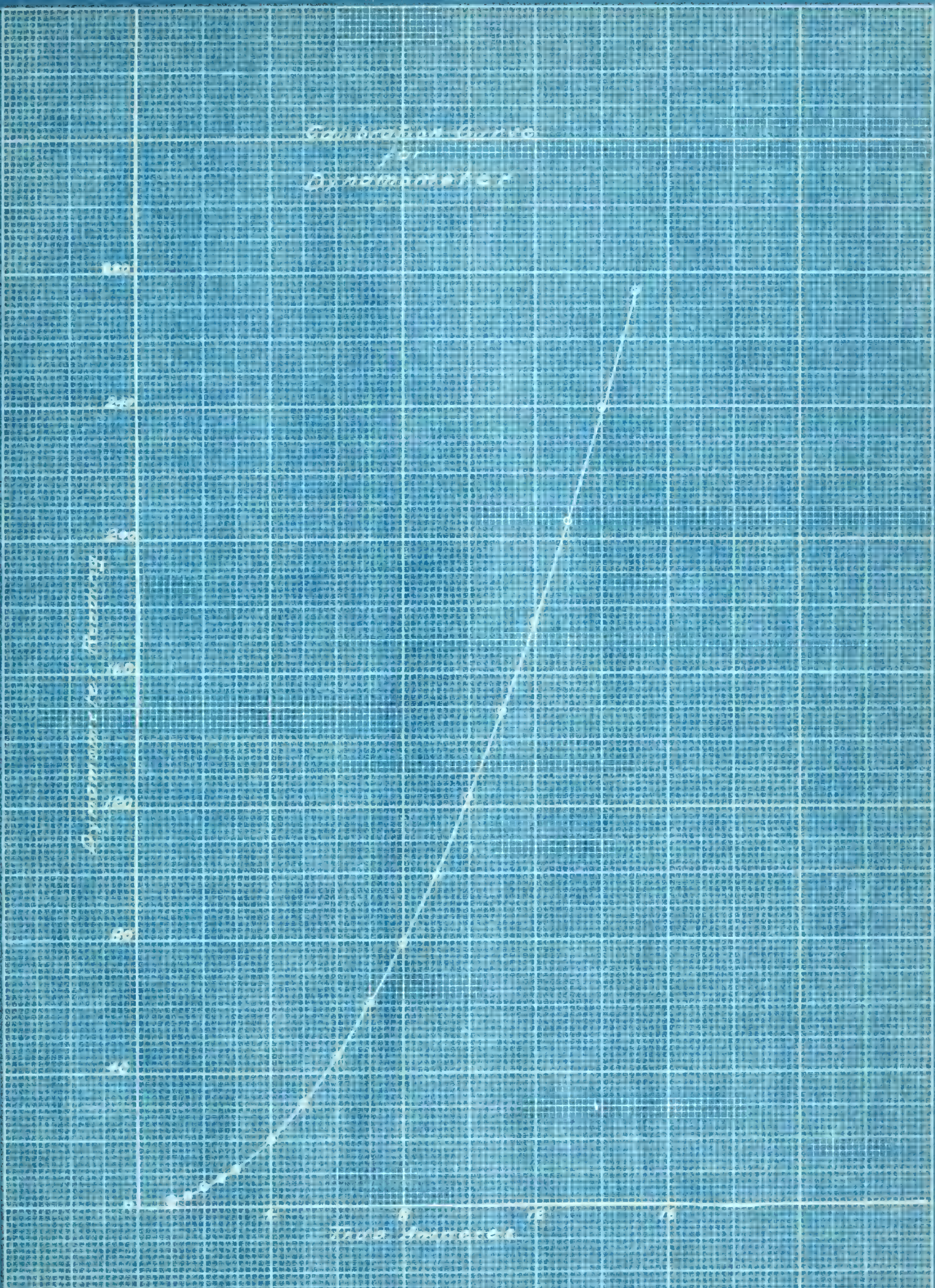
Dynamometer Reading.	True Amperes	Ammeter Reading.
8	2.45	2.2
12	3.1	2.8
16.5	3.6	3.3
19	3.9	3.7
24	4.4	4.2
29	4.82	4.61
36	5.35	5.1
40	5.70	5.5
45.5	6.05	5.88
60	6.95	6.78
80	8.10	8.00
98.5	9.00	8.89
138	10.60	10.50
165	11.65	11.53
189.5	12.45	12.37
214	13.30	13.20
245	14.20	14.10
286	15.35	15.25

Calibration Data for Weston Wattmeter # 466.

Volts.	Amperes	True Watts	Wattmeter Reading.
100	1.23	123	103
"	1.70	170	140
"	2.23	223	200
"	2.60	260	237
"	3.42	342	315
"	3.78	378	353
"	4.28	428	408
"	4.58	458	440
"	5.60	560	546
"	6.40	640	624
"	7.20	720	710
"	8.05	805	800
"	9.03	903	897
"	9.90	990	986
"	11.42	1142	1140
"	12.22	1222	1222
"	13.20	1320	1318
"	13.95	1395	1395
"	14.75	1475	1476
"	15.60	1560	1560
"	16.15	1615	1616

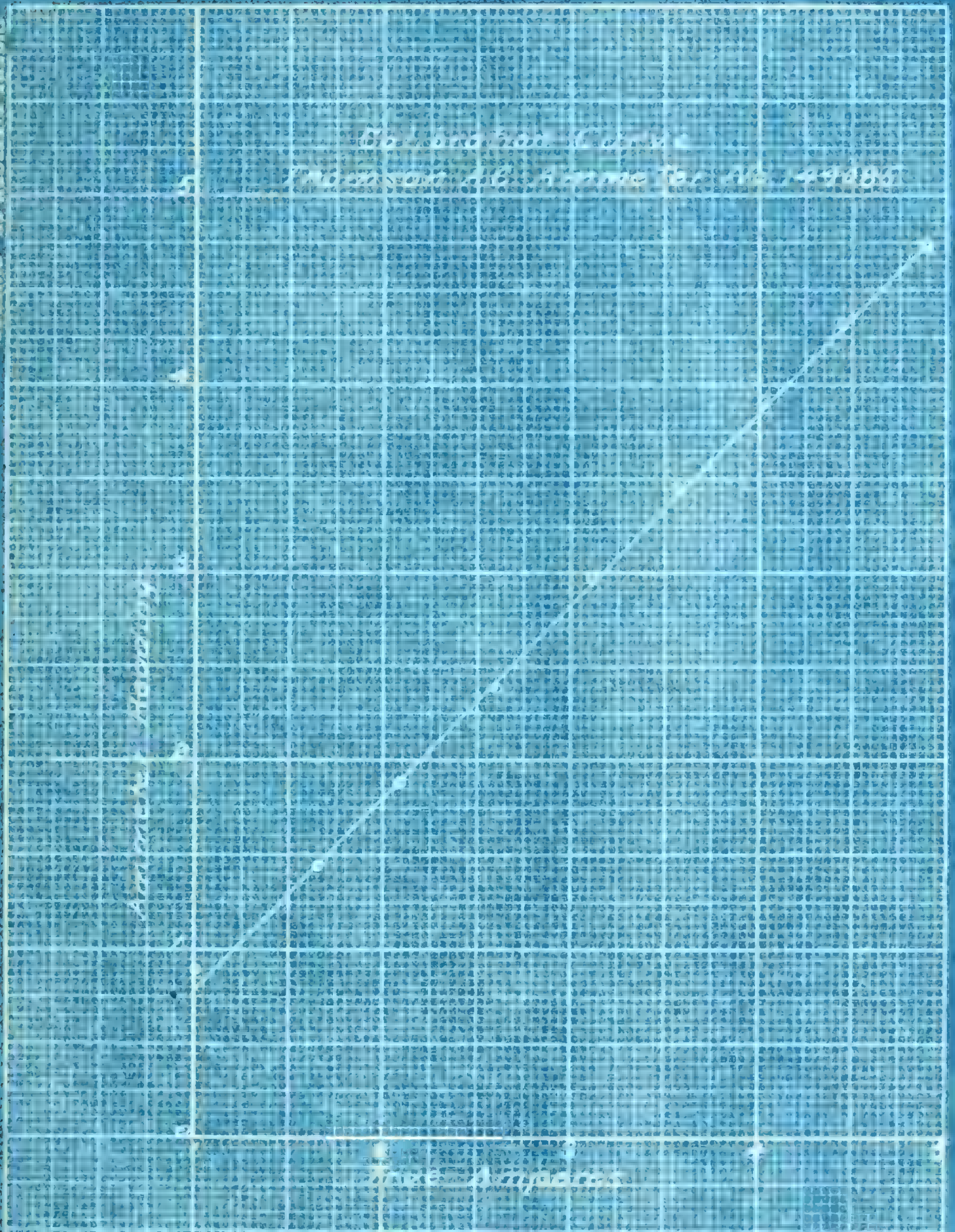

Calibration Curve
for
Dynamometer
Queen and Co's No. 11
160
140
120
100
80
60
40
20
Dynamometer Scale
40
80
120
160
200
240
280
Watts

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.



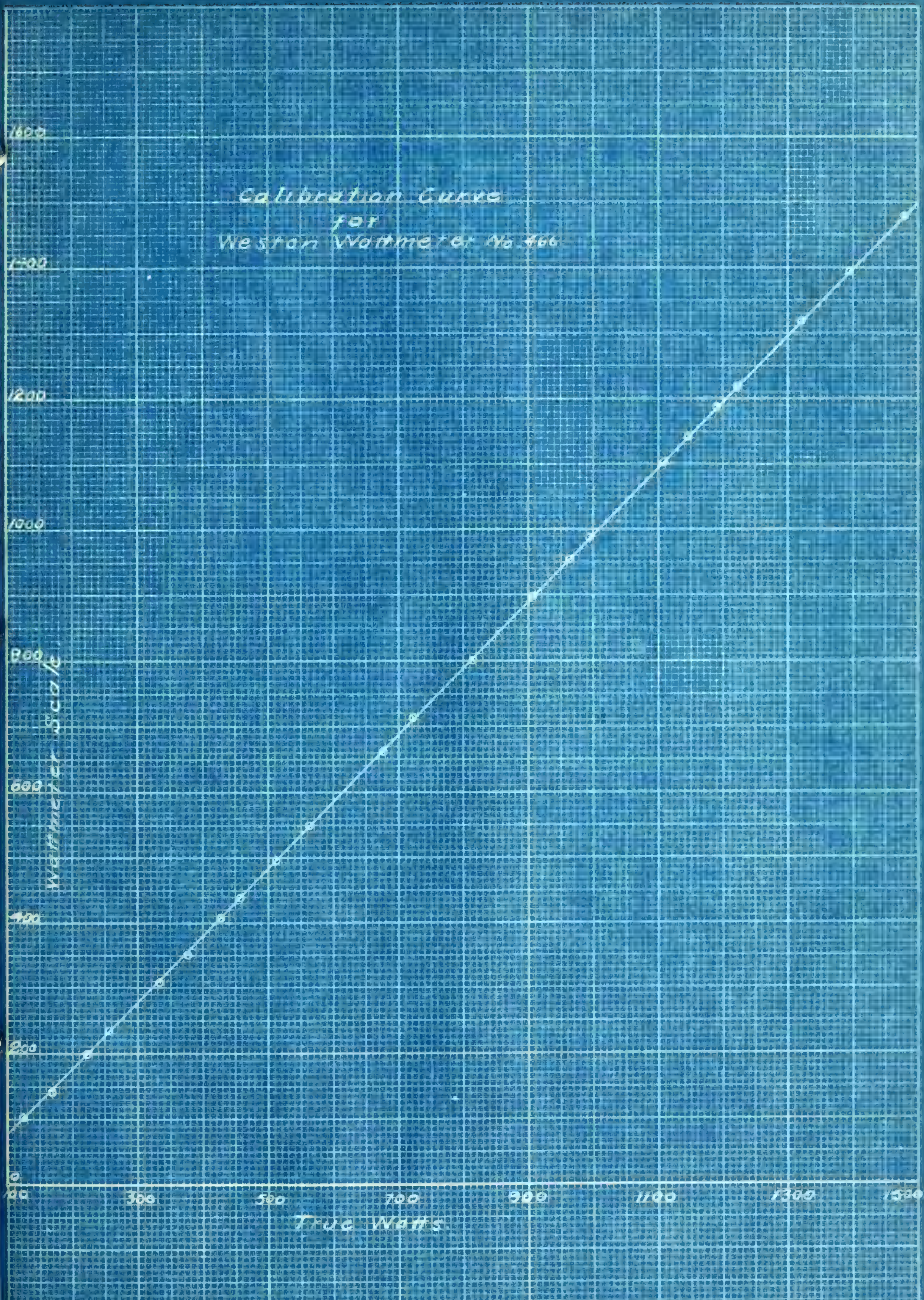
Calibration Curve
for
Dynamometer

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.



CO. CHICAGO-NEW YORK

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.



Calibration Curve
for
Weston Wattmeter No. 466

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

Fort Wayne Meter # 252944.

Resistance of pressure coil .... 357. ohms.

" " series " .... .034 ohms.

Data for the determination of the phase relation of the series and pressure fluxes.

Volts 110 Amperes 10 Apparent Watts 1100

Direction of Rotation of Disc.	Dynamometer Reading.	True Watts	Cos θ.
Forward	-7	13.5	.01228
"	-7.5	14	.01272
"	-6.5	13	.01180
Backward	33	59	.05640
"	35	62	.05640
"	36	64	.05820

Average cos θ for forward rotation .... .01227

" θ " " " .... 90° 42

" cos θ " backward " .... .05620

" θ " " " .... 86° 47.5'

Phase angle from quadrature for forward rotation 42'

" " " " " backward " 3° 12.5'

Average phase angle from quadrature .... 1° 15.25'

Phase angle between series and pressure fluxes . 91° 15.25'

Fort Wayne Meter #252944.

Run # 1.

Data showing the effect of change of load with unity power factor, normal voltage, and normal frequency.

110 volts. 60 cycles. Temperature 76 F

Current	True Watts	R	T	Watts Recorded	% Recorded.
1.15	130	3	100	108	83.2
3.13	345	10	114.5	314	91.2
4.85	537	17	118.5	517	96.3
7.85	870	28	117.2	860	98.8
10.70	1178	38	116.8	1170	99.5
12.85	1420	46	118.0	1405	99.0
14.80	1630	52	115.5	1620	99.5

R is the no. of revolutions made by the disc in T seconds.

Fort Wayne Meter # 252944.

Run # 2.

Data showing the effect of change of load with unity power factor, normal frequency, and 91 % normal voltage.

100 volts. 60 cycles. Temperature 76 F.

Current	True Watts	R	T	Watts Recorded	% Recorded.
1.10	110	2	86	84	76.3
3.25	325	10	120	300	92.5
5.00	500	16	120	480	96.0
7.68	770	25	117.3	768	99.8
10.30	1032	35	121	1040	100.8
12.45	1248	41	118.3	1245	100.0
15.50	1545	51	117.5	1565	101.3

R is the no. of revolutions made by the disc in T seconds.

Fort Wayne Meter # 252944.

Run # ~~2~~.3

Data showing the effect of change of load with unity power factor, normal frequency, and 109 % normal voltage.

120 volts. 60 cycles. Temperature 78 F.

Current	True Watts.	R	T	Watts Recorded	% Recorded.
1.28	155	3	85	127	82.
3.40	400	12	114.5	377	94.4
4.90	590	18	116.5	557	94.5
7.75	925	30	119.4	905	98.0
10.40	1244	40	118.0	1220	98.5
12.00	1440	47	116.2	1420	98.8
14.65	1760	56	116.8	1725	98.0

R is the no. of revolutions made by the disc in T seconds.

Fort Wayne Meter # 252944.

Run # 4.

Data showing the effect of change of power factor with constant full load current, normal frequency, and normal voltage.

110 volts 10 amperes 60 cycles Temperature 75 F

Cos θ	True Watts	R	T	Watts Recorded	% Recorded
1.000	1100	20	65	1110	101
.976	1075	35	117	1075	100
.907	998	34	122	1000	100.2
.855	940	31	120	930	99.0
.810	890	30	123	880	98.8
.745	820	27	120.5	806	98.4
.700	770	25	119	755	98.0
.622	685	22	119.5	663	96.8
.508	560	18	121	535	95.5

R is the no. of revolutions made by the disc in T seconds.

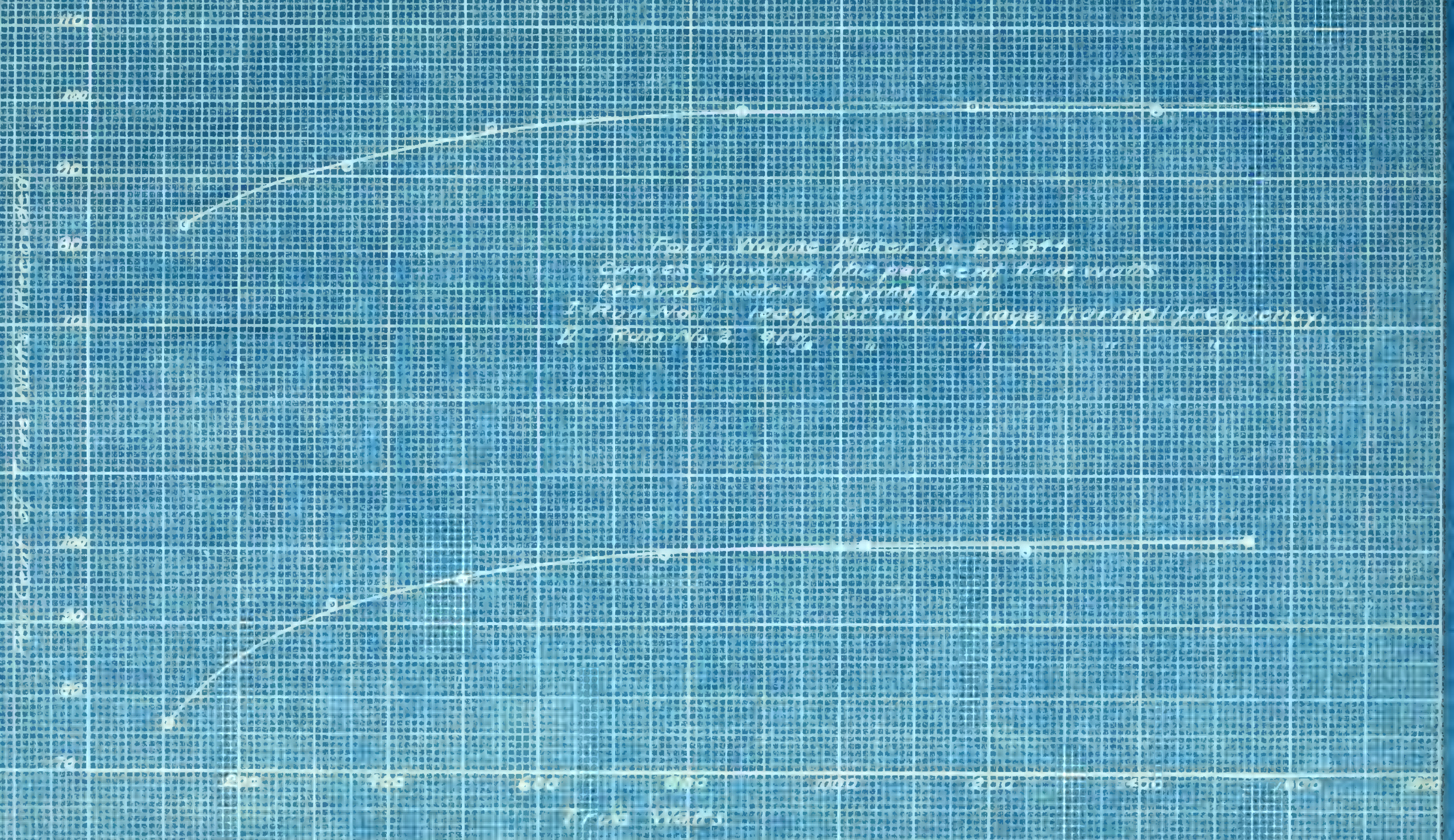
Fort Wayne Meter # 252944.

5.

Data, calculated from the flux quadrature determination, showing the effect of change of power factor with constant full load current, normal frequency, and normal voltage.

110 volts. 10 amperes. 60 cycles.

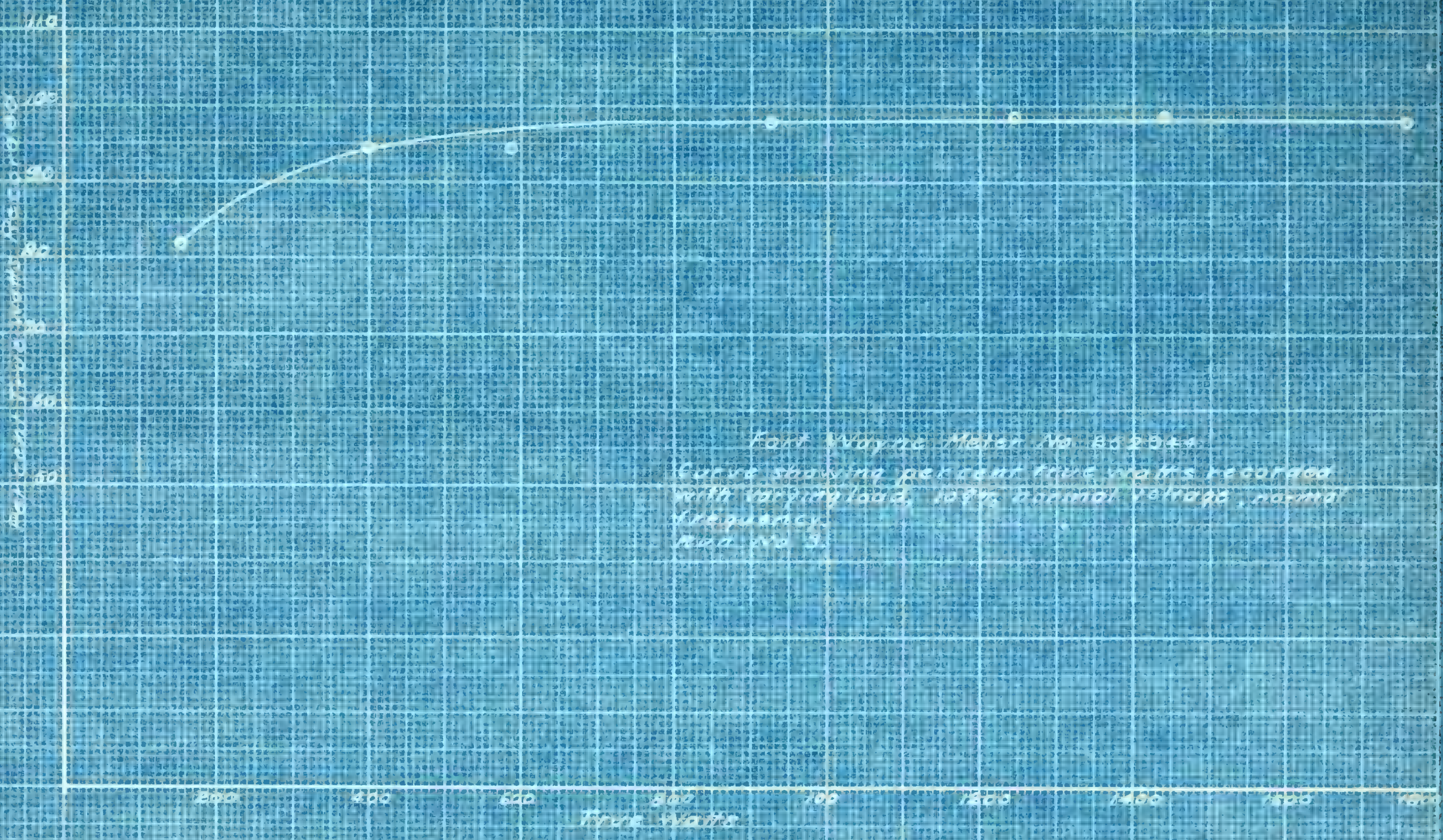
Cos θ.	True Watts.	Watts Recorded.	% Recorded.
1.0000	1100	1100	100.0
.9396	1032	1024	99.5
.8660	954	939	98.5
.7660	844	826	97.9
.6428	708	689	97.4
.5735	631	612	97.0
.5000	550	530	96.3



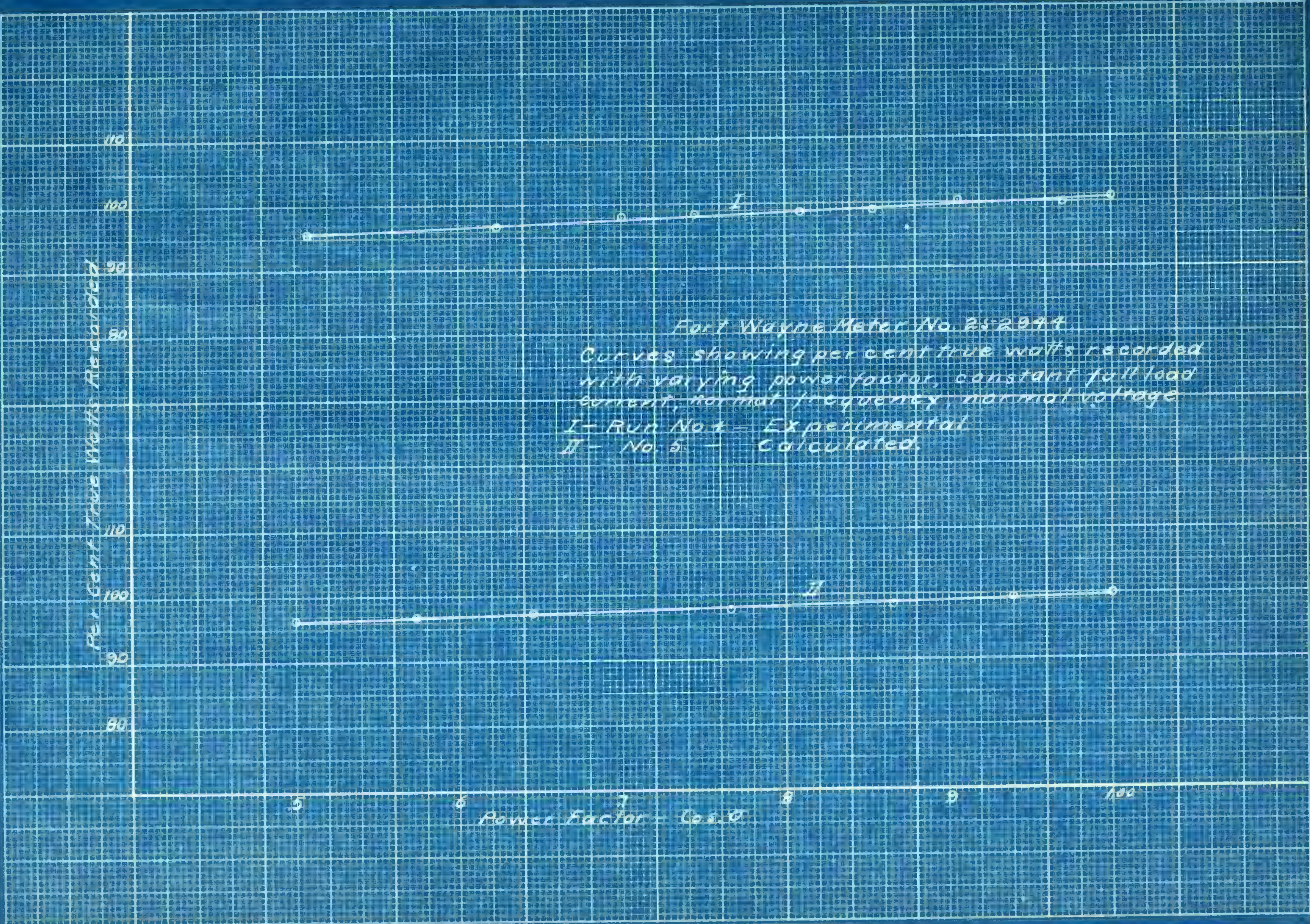
NO 346
EUGENE DIETZGEN CO. CHICAGO-NEW YORK.

6

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.


Fort Wayne Meter No. 862564.
Curve showing per cent true watts recorded with varying load, 10% normal voltage, normal frequency.
Meter No. 3.
per cent true watts recorded
110
100
90
80
70
60
50
200
400
600
800
1000
1200
1400
1600
1800
True Watts

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.



ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

Ferranti Meter # 222322.

Resistance of pressure coil .... 201.0 ohms.

" " series " .... .0225 ohms.

Data for the determination of the phase relation of the series and pressure fluxes.

Volts 110   Amperes 15.8   Apparent Watts 1738.

Direction of Rotation of Disc.	Dynamometer Reading.	True Watts	Cos θ
Forward	13.5	25	.0144
"	12.5	23	.0133
"	15.0	27.5	.0158
Backward	20.5	37	.0212
"	20.5	37	.0212
"	20.0	36	.0207

Average cos θ for forward rotation .... .0145

" " " " backward " .... .02103

" θ " forward " .... 89° 10'

" " " backward " .... 88° 47'

Phase angle from quadrature for forward rotation 50'

" " " " " backward " 1° 13'

Average phase angle from quadrature .... 1° 1.5'

Phase angle between series and pressure fluxes .. 91° 1.5'

Ferranti Meter # 222322.

Run # 1.

Data showing the relation between the load and the % of true watts recorded with unity power factor, normal frequency, and 100 % normal voltage.

110 volts. 60 cycles. Temperature 77 F.

Current	True Watts	R	T	Watts Recorded	% Recorded
1.00	130	10	151	110.5	85.0
2.54	280	20	127.5	262.	93.6
3.95	435	32	127	422	97.0
5.90	650	50	128	653	100.2
8.95	985	75	126.5	990	100.5
11.40	1253	100	133	1256	100.2
13.25	~~1255~~ 1460	120	137	1462	100.0
15.75	1740	140	137	1706	98.0

R is the no. of revolutions made by the disc in T seconds.

Ferranti Meter % 222322.

Run # 2.

Data showing the relation between the load and the % of true watts recorded with unity power factor, normal frequency, and 91 % normal voltage.

Current	True Watts	R	T	Watts Recorded	% Recorded
1.13	125	10	146	114.4	91.4
2.75	270	21	136	258	95.5
5.75	578	46	132	582	100.5
8.98	900	68	126	902	100.2
11.43	1153	90	131	1148	97.0
13.23	1325	100	126	1325	100.0
15.40	1540	120	131	1530	99.5

R is the no. of revolutions made by the disc in T seconds.

Ferranti Meter # 222322.

Run # 3

Data showing the relation between the load and the % of true watts recorded with unity power factor, normal frequency, and 109 % normal voltage.

120 volts. 60 cycles. Temperature 77 F.

Current	True Watts	R	T	Watts Recorded	% Recorded.
1.15	140	10	135	123.8	88.5
3.34	400	28	121	387	96.6
5.85	700.8	50	118	707	100.8
9.65	1160	88	127	1157	99.8
12.50	1500	110	122.5	1500	100.0
15.60	1880	150	136	1912	101.5

R is the no. of revolutions made by the disc in T seconds.

Ferranti Meter # 222322.

Run # 4.

Data showing the relation between the load and the % of true watts recorded with unity power factor, 100 % normal voltage, and 25 cycles, temperature 75 F.

Current.	True Watts.	R.	T.	Watts Recorded.	% Recorded.
1.10	120	7	116	101	84.3
3.45	378	25	117	368	97.3
5.25	574	39	117	558	97.5
7.45	822	56	118.4	780	96.8
9.50	1042	69	115	990	96.8
11.60	1278	85	115	1220	97.2
13.20	1455	95	114	1395	95.7
15.10	1665	109	115.3	1585	95.3

R is the no. of revolutions made by the disc in T seconds.

Ferranti Meter #222322.

Run # 5

Data showing the effect of change of load at normal voltage, unity power factor and 25 cycles.

110 volts 25 cycles Temperature 80 F

Current	True Watts	R	T	Watts Recorded	% Recorded
1.54	169.4	12	132	152	89.25
3.52	387.8	30	139	361	93.1
6.88	757.5	60	136.5	735	97.0
9.30	1022.0	77	128	1005	98.5
12.68	1393.0	100	124.7	1338	96.0
15.32	1686	121	125	1617	96.0

R is the no. of revolutions made by the disc in T seconds.

Ferranti Meter # 222322.

Run # 6

Data showing the effect of change of power factor with constant full load, normal voltage and 60 cycles.

110 volts. 10.1 amperes. Temperature 80 F.

Cos.θ	True Watts	R	T	Watts Recorded	% Recorded
1.000	1110	40	59.5	1128	102.5
.930	1032	40	63	1060	102.5
.864	958	54	92	985	102.5
.750	832	32	63.5	843	101.5
.672	745	28	62	756	101.5
.620	688	26	62	703	101.7
.567	628	24	63	638	101.5
.516	573	22	63.5	582	101.5

R is the no. of revolutions made by the disc in T seconds.

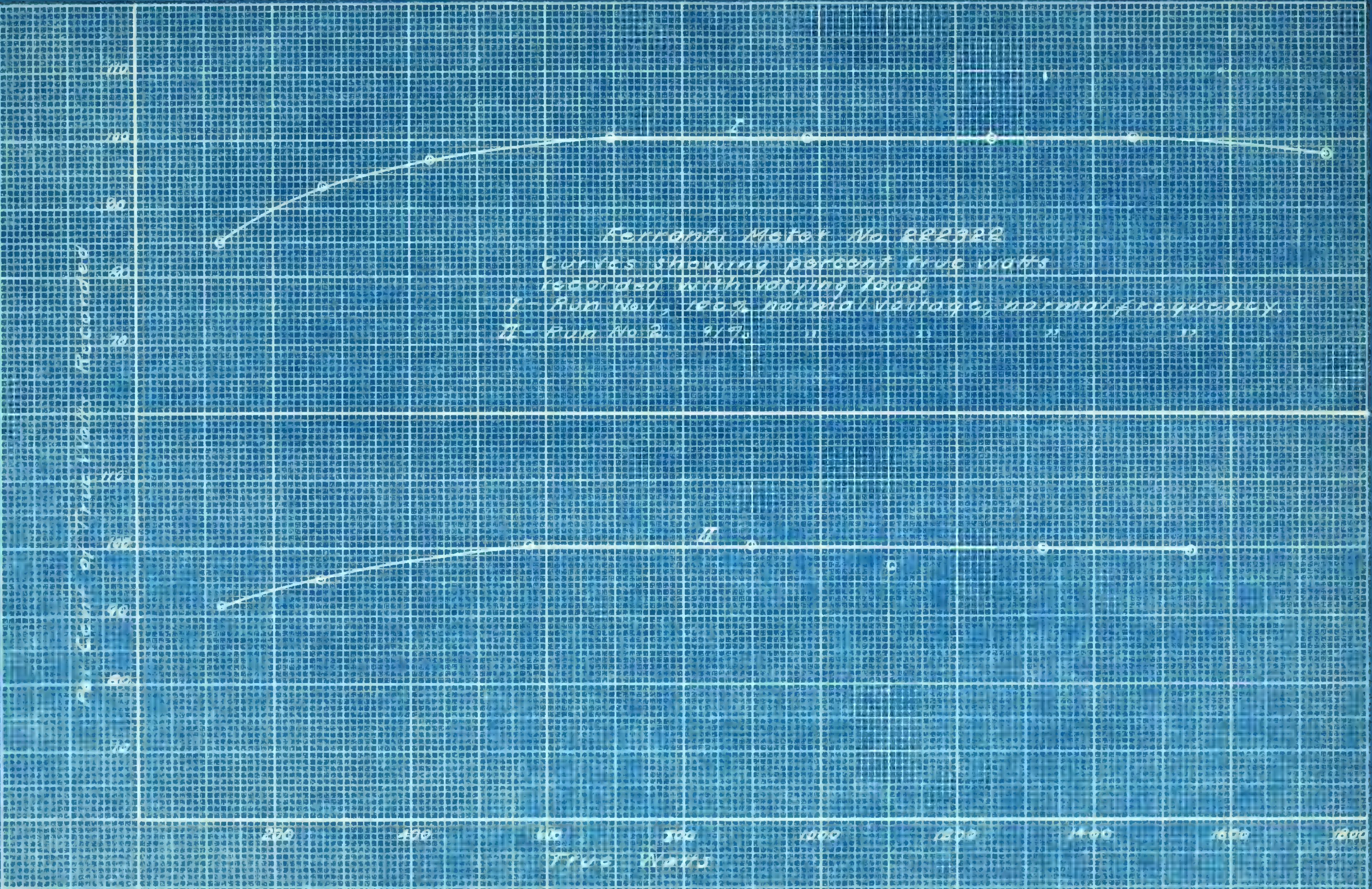
Ferranti Meter # 222322.

#7

Data calculated from the flux quadrature determination showing the effect of change of power factor with constant full load, normal voltage and frequency.

110 volts. 10 amperes. 60 cycles.

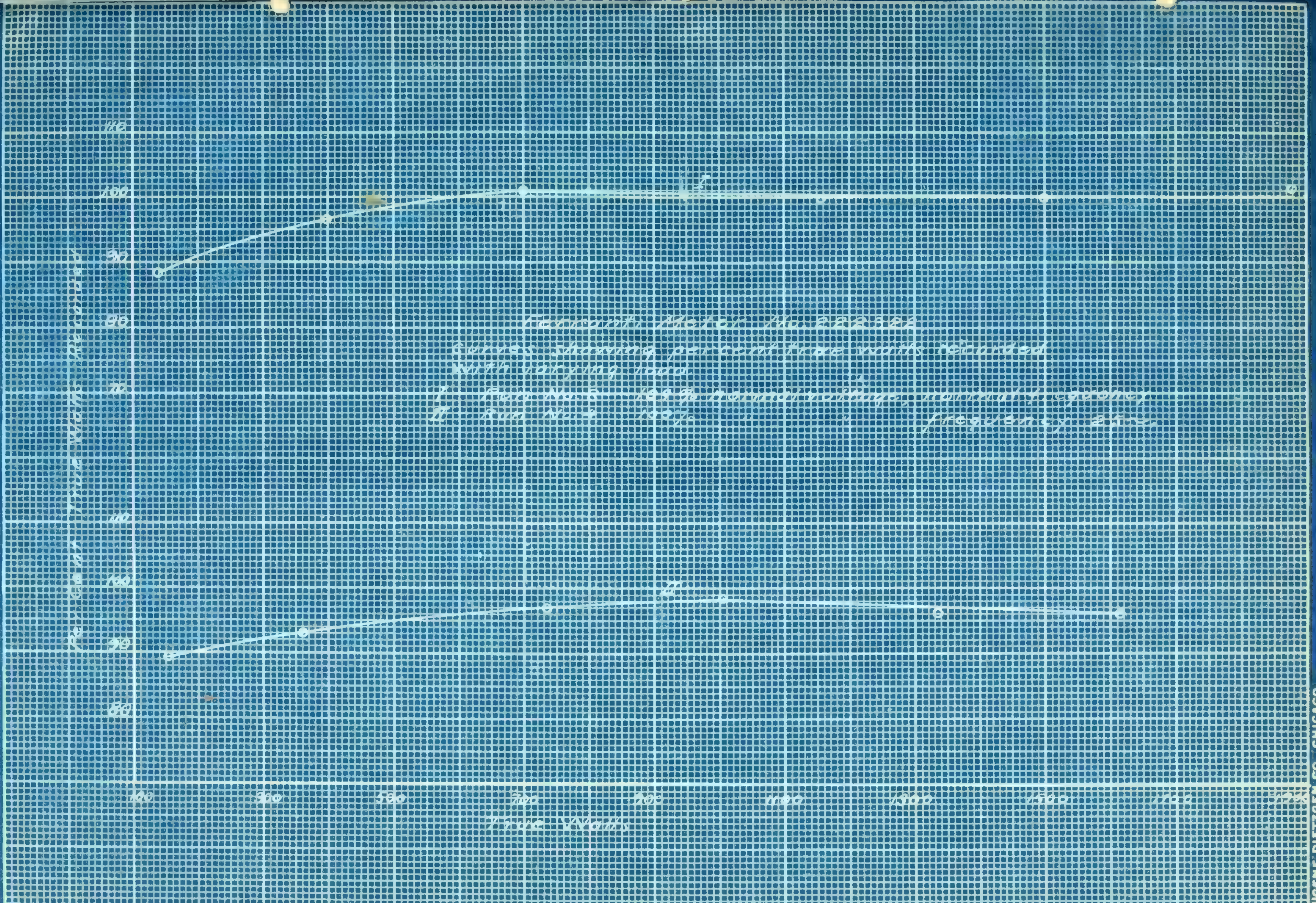
Cos.θ	Watts Recorded	True Watts	% Recorded
1.0000	1099.78	1100	100
.9848	1079.76	1083.28	99.8
.9397	1026.85	1033.67	99.2
.8660	942.70	952.60	98.5
.7660	829.95	824.60	98.3
.6428	692.00	707.00	97.9
.5000	533.00	550.00	97.0



Ferranti Meter No. 222322
Curves showing percent true watts
recorded with varying load
I – Run No. 1, 100% normal voltage, normal frequency.
II – Run No. 2 97% " " " "

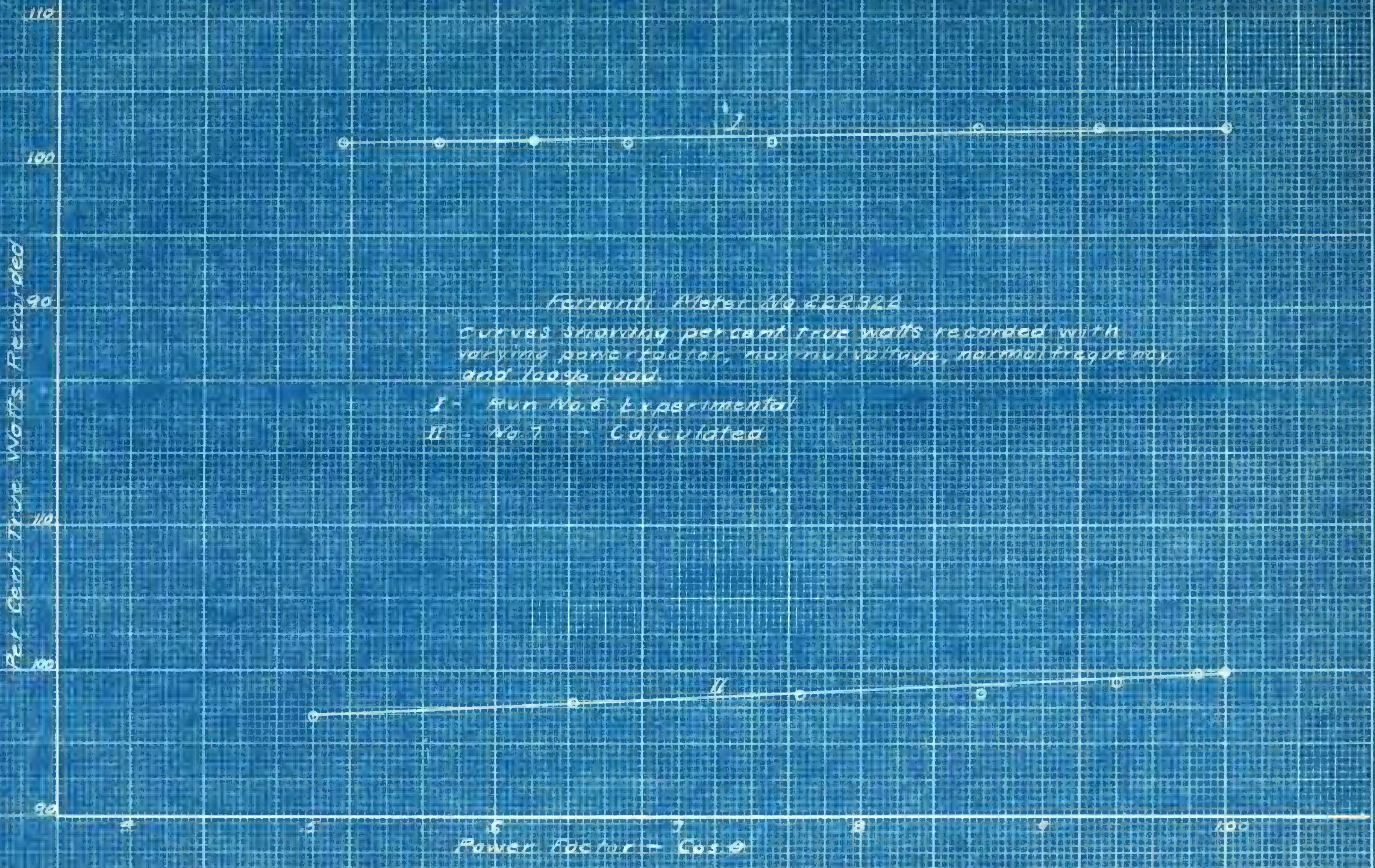
No. 346
Eugene Dietzgen Co., Chicago-New York.

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.



Ferranti Meter No. 222582
Curves showing per cent true watts recorded
with varying load
I Run No. 6 100% normal voltage, normal frequency
II Run No. 7 100% " frequency 25~

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.



Ferranti Meter No 222322

Curves showing per cent true watts recorded with varying power factor, normal voltage, normal frequency and 100% load.

I – Run No 6 Experimental

II – No 7 – Calculated

EUGENE DIETZGEN CO. CHICAGO-NEW YORK

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

Sangamo Meter # 66151.

Resistance of pressure coil .... 204.5 ohms.

" " series " .... .0275 ohms.

Data for the determination of the phase relation of the series and pressure fluxes.

Volts 110 Amperes 15.15 Apparent Watts 1665.

Direction of Rotation of Disc.	Dynamometer Reading.	True Watts	Cos θ.
Forward	-9	17	.0102
"	-11	20.3	.0122
"	-9	17	.0102
Backward	37.5	67	.0415
"	38.5	68.5	.0412
"	37.5	67	.0402

Average cos θ for forward rotation .... .0109

" θ " " " .... 90° 37'

" cos θ " backward " .... .0410

" θ " " " .... 87° 37'

Phase angle from quadrature for forward rotation 37'

" " " " " backward " 2° 23'

Average phase angle from quadrature .... 53'

Phase difference between series and pressure fluxes 53'

Sangamo Meter # 66151.

Run # 1.

Data showing the effect of change of load with normal voltage, unity power factor, and normal frequency.

110 volts. 60 cycles. Temperature 75 F

Current	True Watts	R	T	Watts Recorded	% Recorded.
1.6	175	8	115	167	95.5
3.5	383	18	111.8	387	101.
5.0	553	26	111.8	558	101.
7.8	865	40	110	873	101.
10.4	1147	53	111	1146	99.5
12.8	1410	64	111.4	1380	98.
15.2	1680	75	111	1620	96.4

R is the no. of revolutions made by the disc in T seconds.

Sangamo Meter # 66151.

Run # 2

Data showing the effect of change of load with unity power factor, normal frequency, and 109 % voltage.

120 volts 60 cycles Temperature 75 F

Current	True Watts	R	T	Watts Recorded	% Recorded.
1.35	155	7	114.3	147	94.8
3.4	378	18	113.2	381	100.8
4.9	588	28	113.5	593	100.8
7.55	910	43	111.6	925	101.6
10.00	1210	55	110.2	1200	99.4
13.20	1590	70	109.8	1530	96.2
15.20	1840	79	110.4	1720	93.4

R is the no. of revolutions made by the disc in T seconds.

Sangamo Meter # 66151.

Run # 3

Data showing the effect of change of load with unity power factor, normal frequency, and 91 % normal voltage.

100 volts. 60 cycles. Temperature 75 F

Current	True Watts	R	T	Watts Recorded	% Recorded.
1.45	150	6	103	140	96.5
3.35	335	16	114.8	335	100.0
5.50	560	27	113.3	572	102.0
7.75	780	37	112.5	790	101.3
9.90	998	47	111.3	1012	101.3
12.50	1253	57	110.0	1245	99.3
14.50	1470	66	110.0	1440	98.0

R is the no. of revolutions made the disc in T seconds.

Sangamo Meter # 66151.

Run # 4.

Data showing the effect of change of power factor with constant full load, normal voltage and 60 cycles.

110 volts. 10.1 amperes Temperature 80 F.

Cos.θ	True Watts	R	T	Watts Recored	% Recdrded
1.000	1147	53	111	1146	99.5
.92	1020	27	63	1029	101.0
.863	958	25	62	970	101.0
.855	950	25	64	938	99.0
.783	870	22	61	866	99.7
.703	780	24	74	778	99.7
.653	725	19	63.5	718	99.6
.594	660	18	66	655	99.3
.514	588	15	62	581	98.8

R is the no. of revolutions made by the disc in T seconds.

Sangamo Meter # 66151.

5.

Data, calculated from the flux phase determination, showing the effect of change of power factor with constant full load current, normal frequency, and normal voltage.

Volts 110 Amperes 10 Cycles 60.

Cos θ	Watts Recorded.	True Watts.	% Recorded.
1.000	1100	1100	100
.984	1080	1083	99.7
.940	1028	1033	99.4
.866	944	954	99.0
.766	832	843	98.7
.643	695	707	98.3
.500	535	550	97.3

Sangamo Meter # 66151.

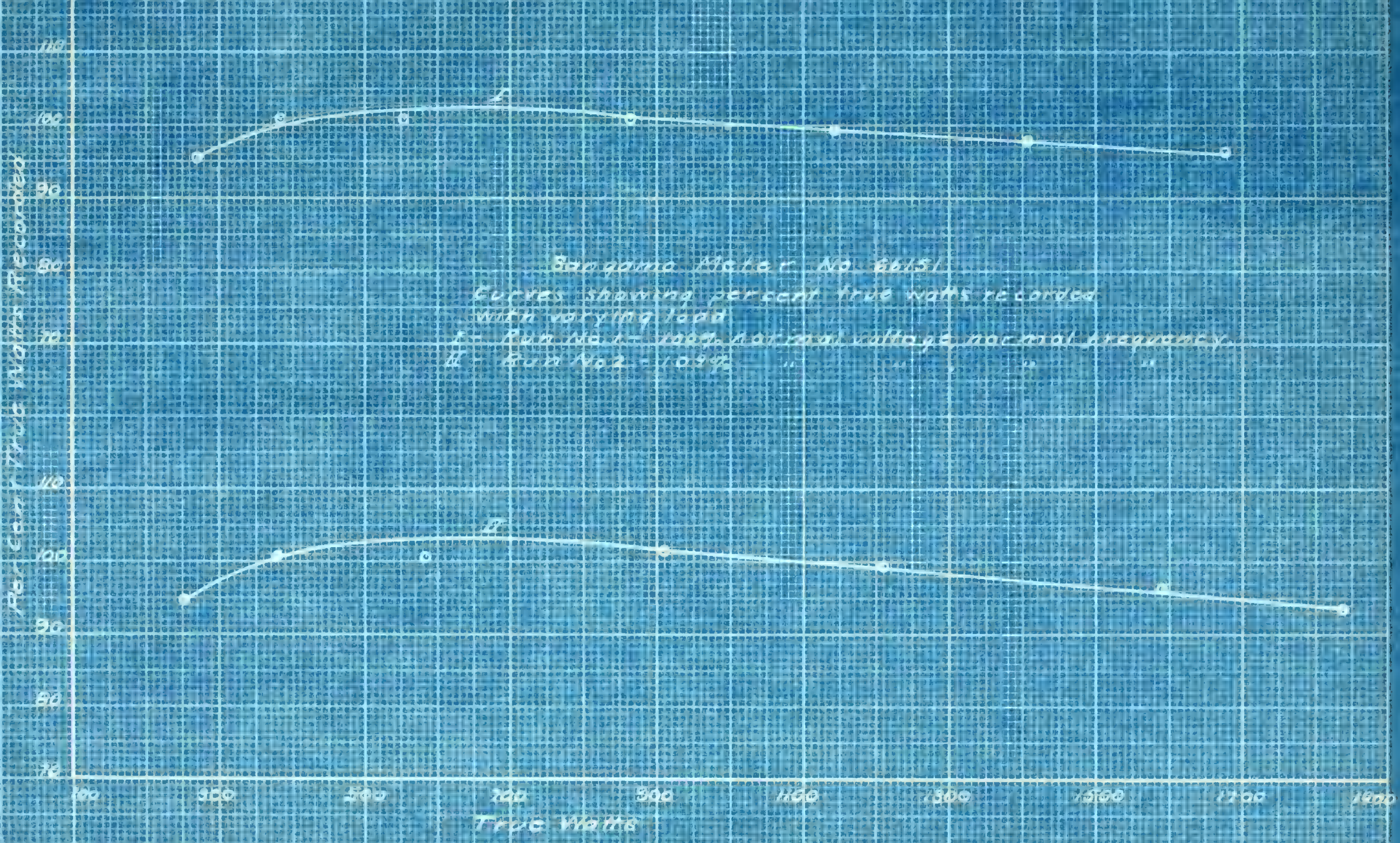
Run # 6.

Data showing the effect of change of load with unity power factor, normal voltage, and normal frequency.

110 volts. 120 cycles. Temperature 70 F.

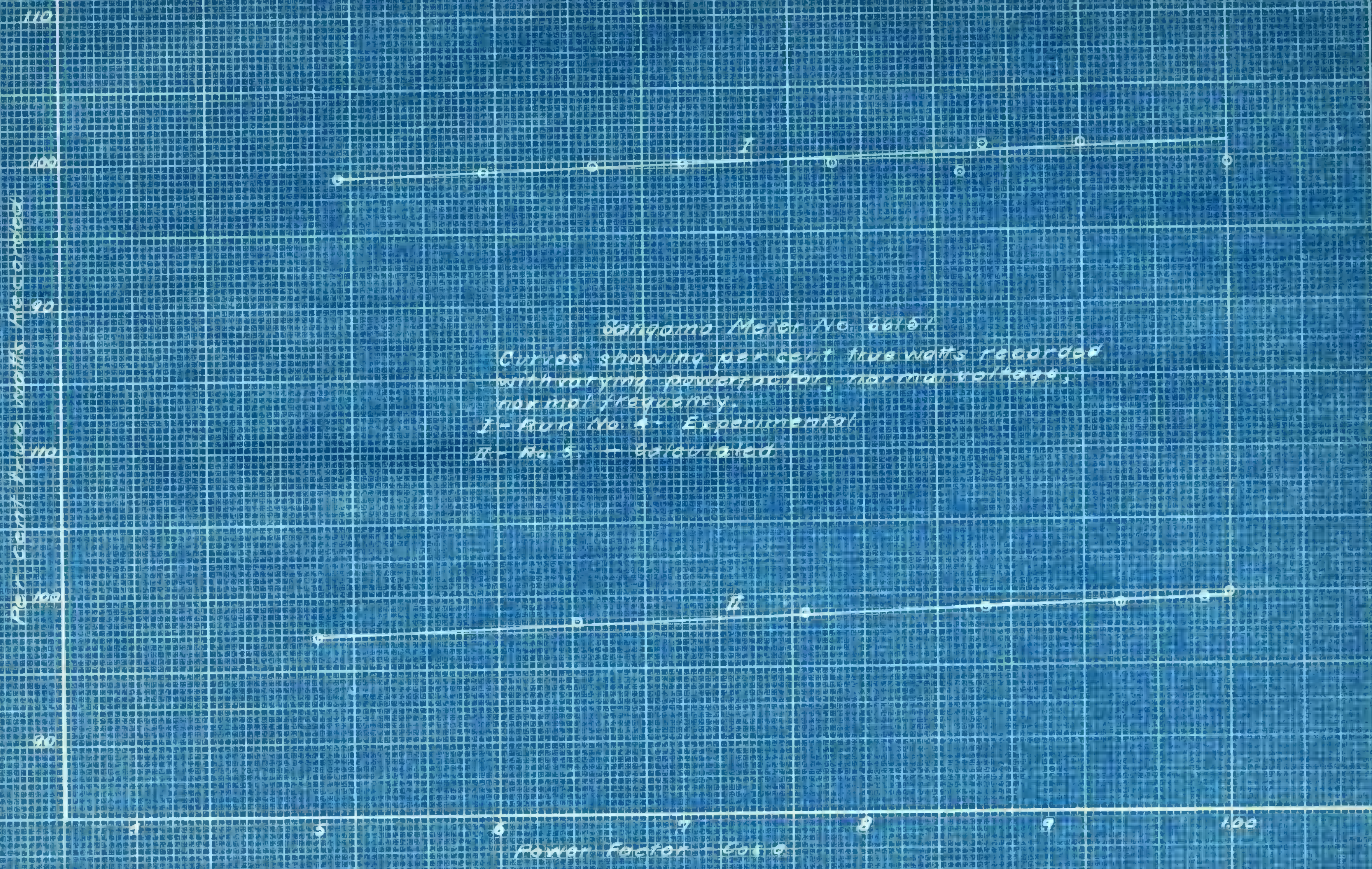
Current	True Watts	R.	T.	Watts Recorded.	% Recorded.
1.20	132	5	106	113	85.7
2.55	280	12	113	255	91.0
3.85	425	19	112	408	96.0
5.10	560	30	126	572	102.0
7.20	845	39	111	844	99.9
12.20	1345	57	105	1305	97.0
15.00	1640	68	104.2	1565	95.4

R is the no. of revolutions made by the disc in T seconds.



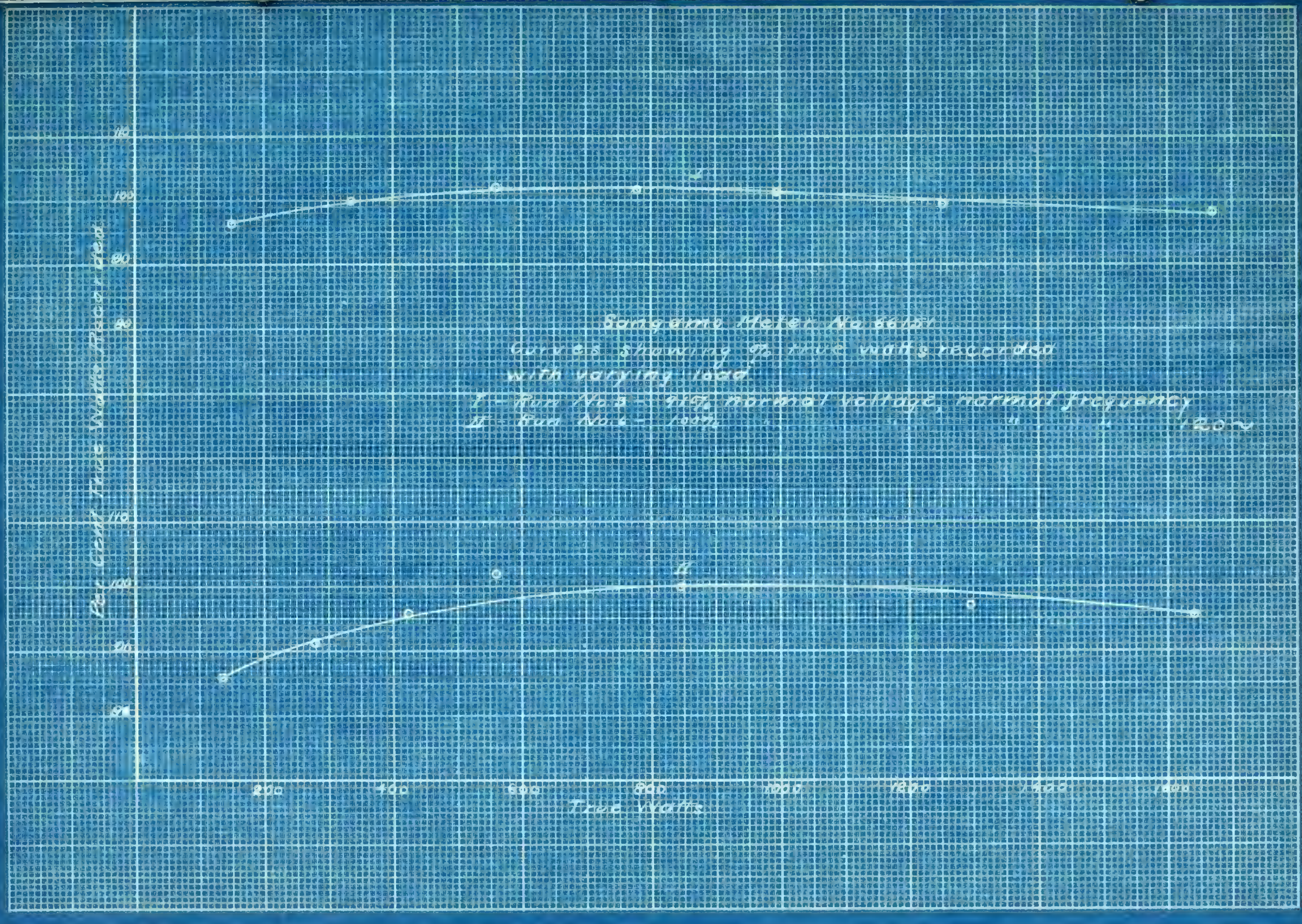
EUGENE DIETZGEN CO. CHICAGO-NEW YORK

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.



EUGENE DIETZGEN CO. CHICAGO-NEW YORK

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

Sangamo Meter No. [illegible]
Curves showing % true watts recorded
with varying load
I – Run No. 3 – 91% normal voltage, normal frequency
II – Run No. 2 – 100% " " 120~
Per Cent True Watts Recorded
110
100
90
80
110
100
90
80
200
400
600
800
1000
1200
1400
1600
True Watts
I
II

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

Sangamo Meter # 76671.

Resistance of pressure coil .... 317. ohms.
" " series " .... .04 ohms.

Data for the determination of the phase relation of the series and pressure fluxes.

Volts 110 Amperes 5 Apparent Watts 550.

Direction of Rotation of Disc.	Dynamometer Reading.	True Watts	Cos θ.
Forward	14	26	.0473
"	14	26	.0473
"	14	26	.0473
Backward	1	2.8	.0051
"	1	2.8	.0051
"	2	5.0	.0091

Average cos θ for forward rotation .... .0473
" θ " " " .... 87° 17'
" cosθ " backward " .... .0064
" θ " " " .... 89° 38'

Phase angle from quadrature for forward rotation 2° 43'
" " " " " backward " 22'

Average phase angle from quadrature .... 1° 33'

Phase difference between series and pressure fluxes 1° 33'

Sangamo Meter # 76671.

Run# 1.

Data showing the relation between the load and the % of true watts recorded with unity power factor, normal frequency, and normal voltage.

110 volts. 60 cycles. Temperature 76 F.

Current.	True Watts.	R	T	Watts Recorded.	% Recorded.
1.1	120	5	82.5	109	91.8
1.78	195	11	105.3	188	96.4
2.50	275	16	105.3	274	99.7
3.00	330	19	102.8	333	100.8
3.85	422	28	118.0	427.5	101.0
4.80	528	30	100.4	538	101.7
5.65	622	37	106.3	625	100.5
7.40	812	47	104.3	810	99.8

R is the no. of revolutions made by the disc in T seconds.

Sangamo Meter # 76671.

Run # 2

Data showing the relation between the load and the % of true watts recorded with unity power factor, normal frequency, and 91% of normal voltage.

100 volts. 60 cycles. Temperature 76 F

Current.	True Watts	R	T	Watts Recorded	% Recorded.
1.1	115	6	105.5	102.5	89.0
2.25	225	13	111.	211	93.6
3.15	317	19	108.	316	99.7
4.15	415	25	108.	416	100.2
5.18	518	31	106.2	525	101.2
6.25	626	36	103.5	626	100.0
7.50	752	45	107.6	752	100.0

R is the no. of revolutions made by the disc in T seconds.

Sangamo Meter # 76671.

Run # 3.

Data showing the relation between the load and the % of true watts recorded, unity power factor, normal frequency, and 109 % normal voltage.

120 volts. 60 cycles. Temperature 76 F.

Current.	True Watts	R	T	Watts Recorded	% Recorded.
1.12	135	7	102.5	123	91.
2.05	247	14	107.2	235	95.2
2.85	340	20	106.2	338	99.5
3.65	433	26	107.5	435	100.5
4.52	544	32	105.2	547	100.7
5.50	660	38	104.0	658	99.75
6.40	770	45	106.0	765	99.4
7.40	888	51	105.0	875	98.5

R is the no. of revolutions made by the disc in T seconds.

Sangamo Meter # 76671.

Run # 4.

Data showing the effect of change of power factor with constant full load current, normal voltage, and normal frequency.

110 volts. 60 cycles. 5 amperes. Temperature 76 F.

Cos.θ.	True Watts.	R.	T.	Watts Recorded.	% Recorded.
1.000	550	32	103.	560	101.5
.928	510	30	104.2	518	101.5
.850	468	28	105.5	478	102.2
.763	420	27	111.5	436	103.7
.695	382	25	114.	395	103.4
.570	313	23	128.	324	103.4

R is the no. of revolutions made by the disc in T seconds.

Sangamo Meter # 76671.

5.

Data, calculated from the flux phase determination, showing the effect of change of power factor with normal frequency, normal voltage, and constant full load current.

Volts 110 Amperes 5. Cycles 60.

Cos θ	True Watts	Watts Recorded	% Recorded.
1.0000	550	550	100.0
.9848	542	544	100.5
.9400	517	522	100.8
.8660	477	483	101.2
.7660	422	431	102.0
.6430	354	364.5	103.0
.5000	275	287.5	104.5

Sangamo Meter # 76671.

Run # 6

Data showing the effect of change of load with unity power factor, normal voltage ,and normal frequency.

110 volts. 25 cycles. Temperature 70 F.

Current.	True Watts.	R.	T.	Watts Recorded.	% Recorded.
1.16	128	7	110.2	114	89.2
1.55	170	10	114.0	158	93.0
2.50	275	17	113.0	271	98.5
3.50	383	26	122.0	384	100.2
4.50	495	32	116.0	497	100.3
5;80	640	41	114.5	645	100.6
7.30	805	53	119.5	800	99.4

R is the no. of revolutions made by the disc in T seconds.

Sangamo Meter # 76671.

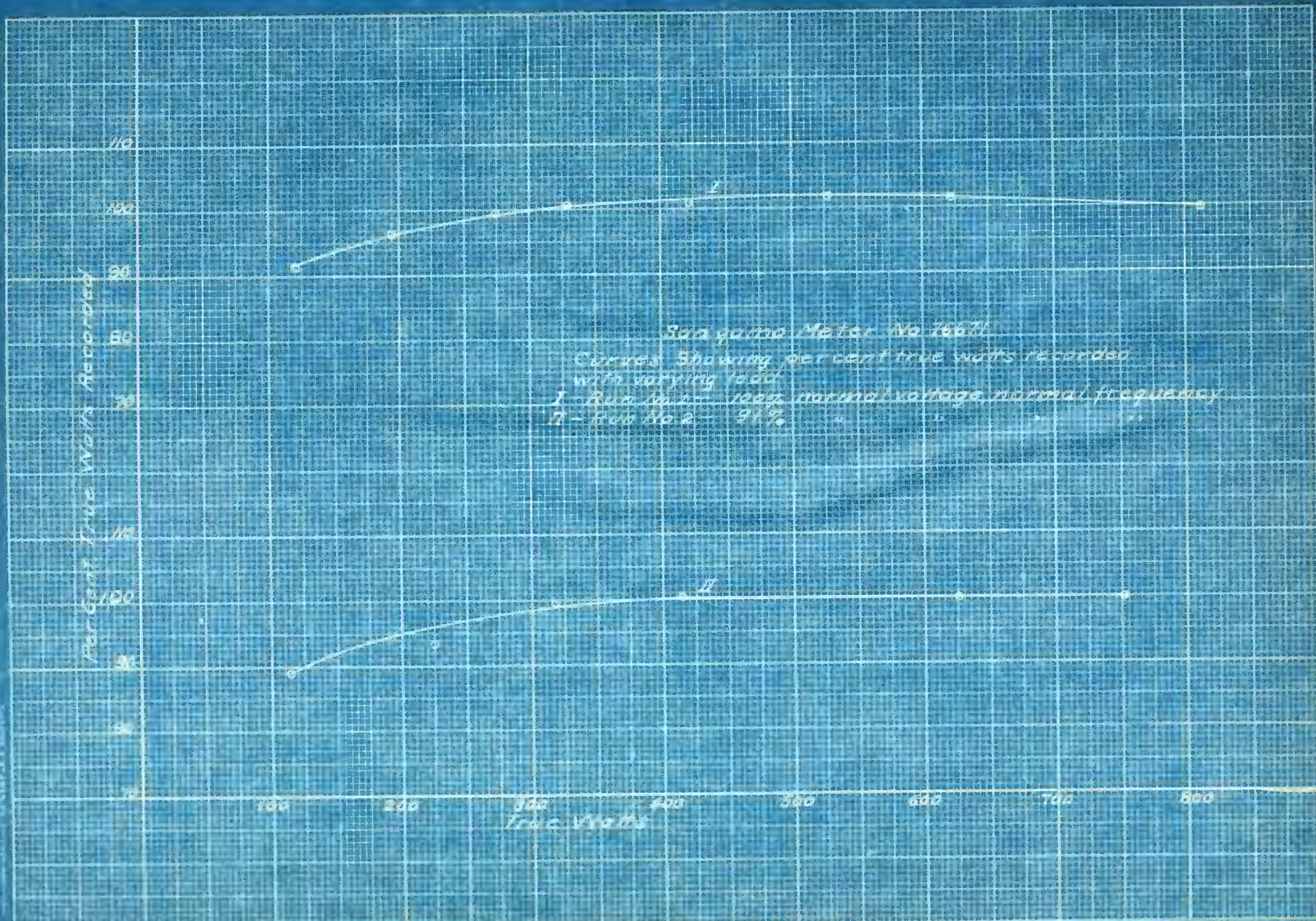
Run # 7.

Data showing the effect of change of load with unity power factor, normal voltage, and normal frequency.

110 volts. 120 cycles. Temperature 70 F.

Current	True Watts	R.	T.	Watts Recorded.	% Recorded.
1.10	120	6	100.5	107.5	89.7
1.55	170	10	114	158	93.0
2.50	277	16	106	272	98.3
3.40	375	22	106	374	99.8
4.45	490	24	87	495	101.0
4.95	545	36	119	545	100.0
7.25	795	40	91	792	99.6

R is the no. of revolutions made by the disc in T seconds.



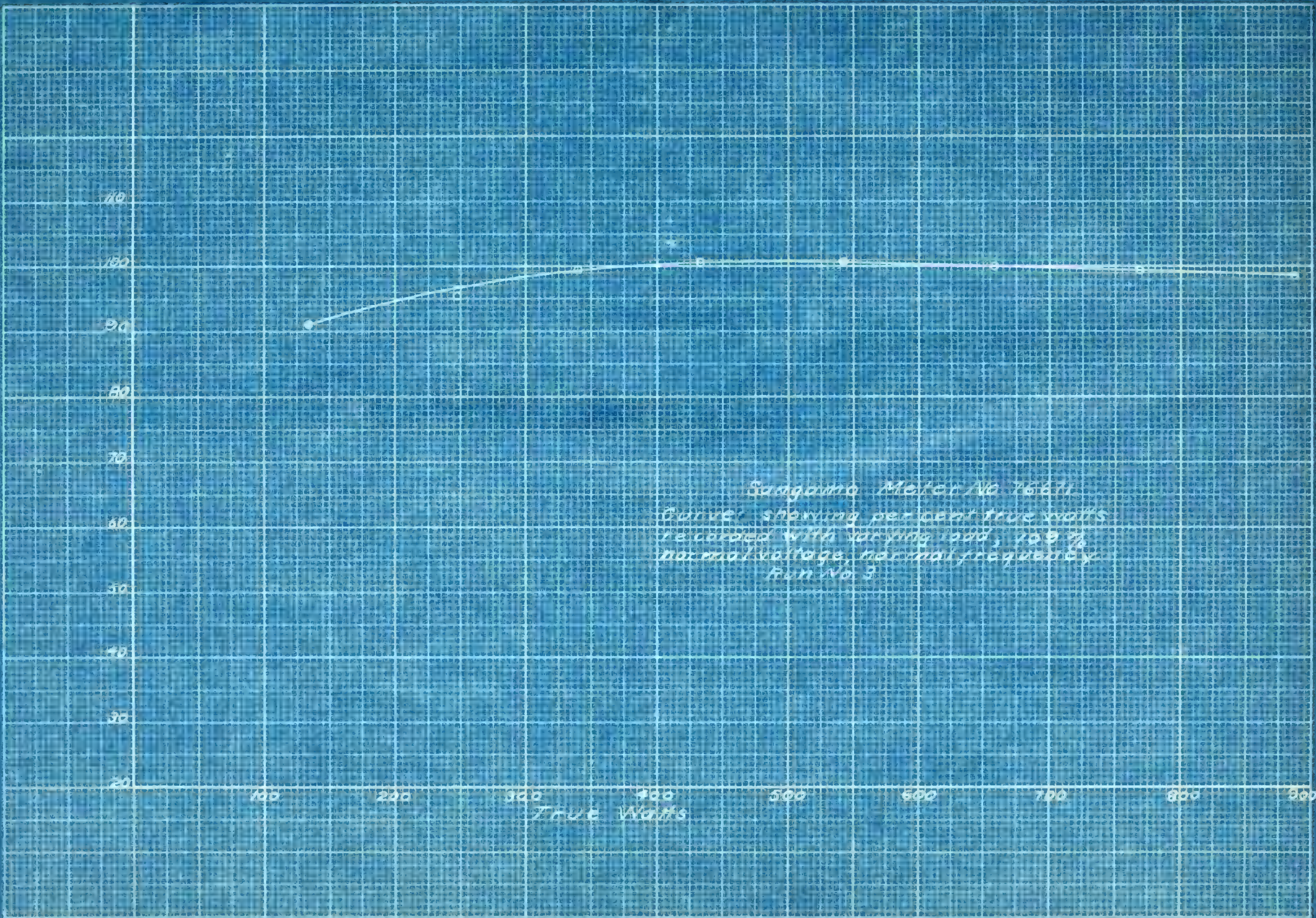
Sangamo Meter No 76671

Curves Showing per cent true watts recorded with varying load

I – Run No 1 – 100% normal voltage normal frequency

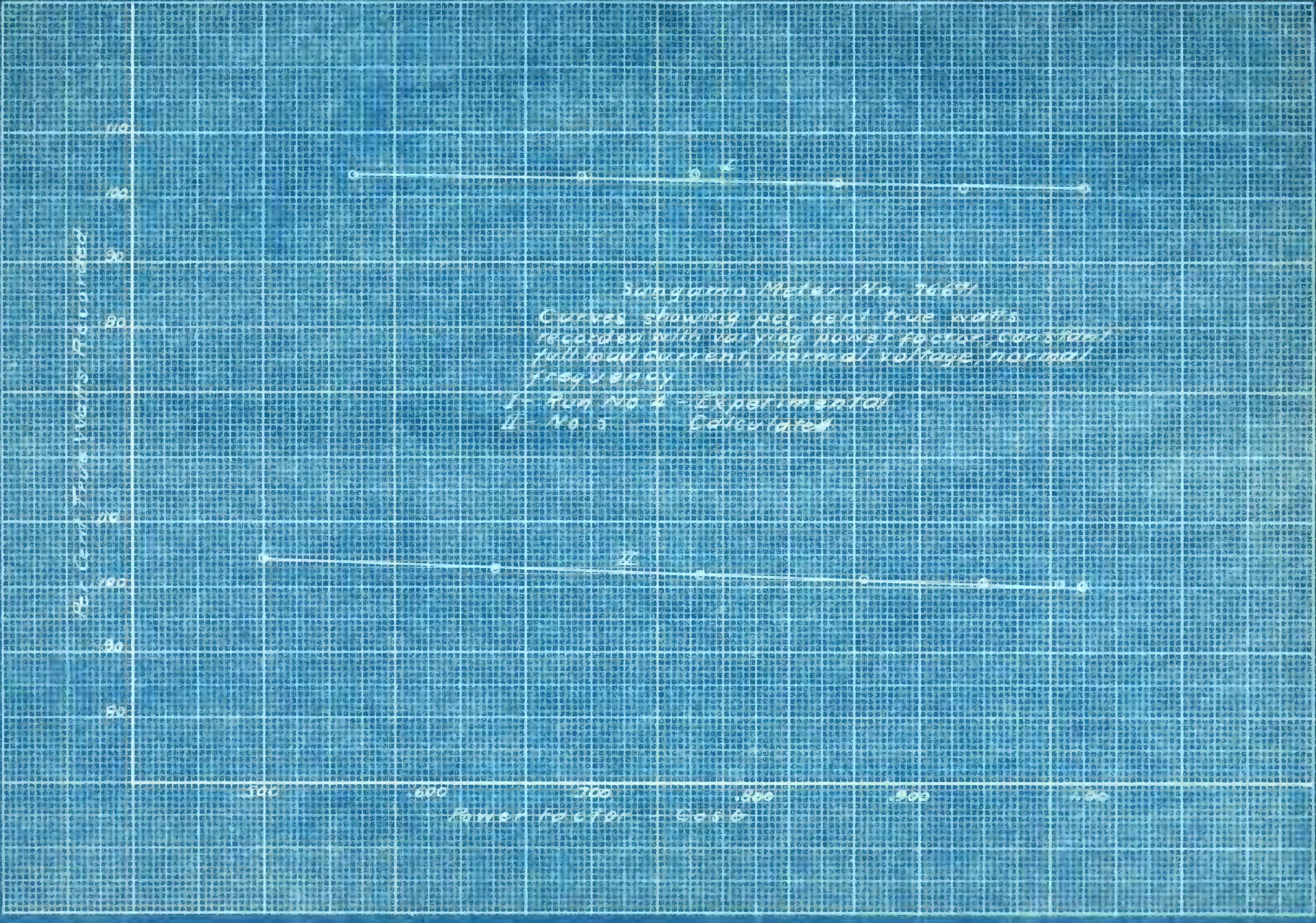
II – Run No 2 – 91%

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.



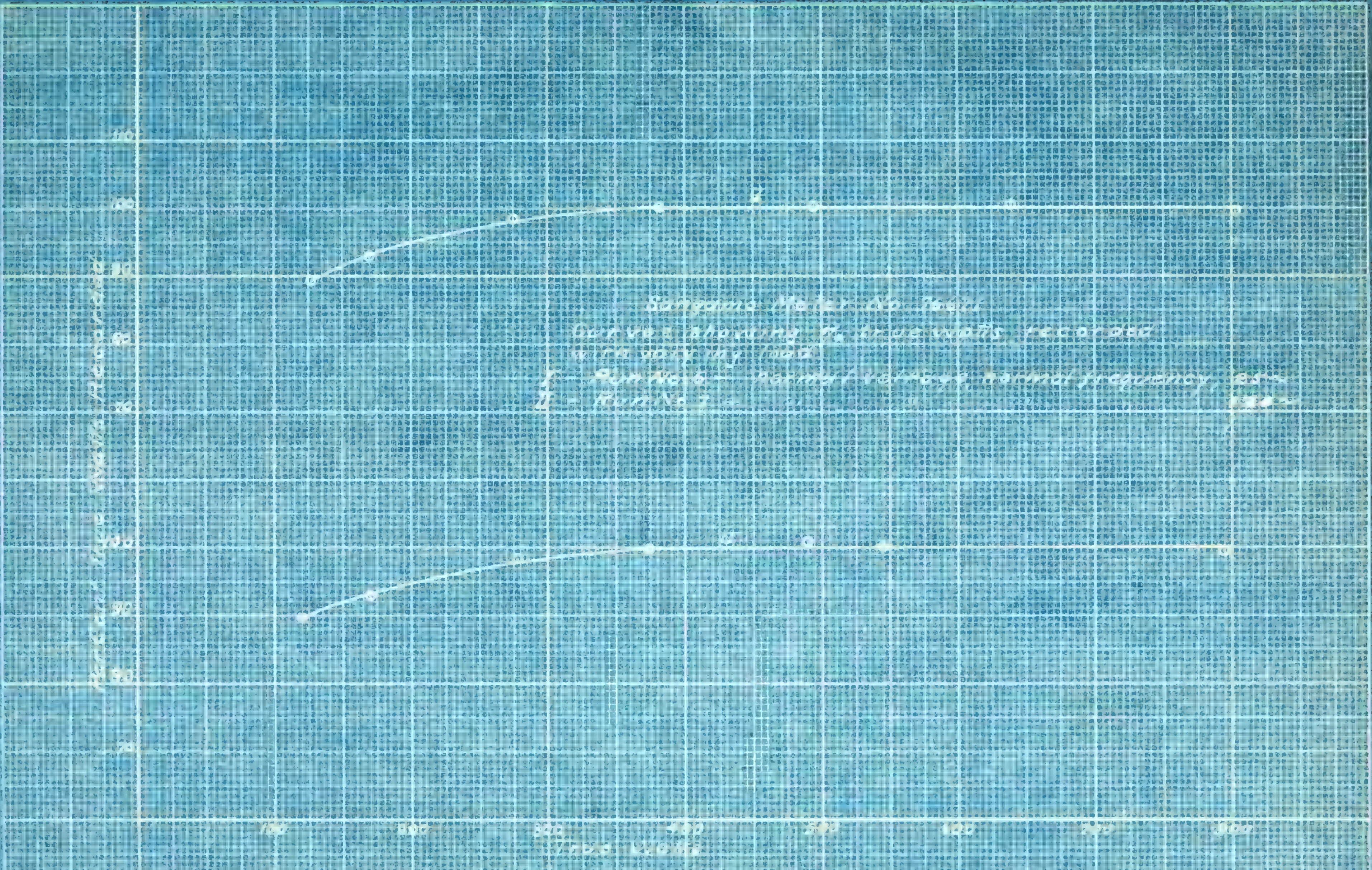
Sangamo Meter No 76671
Curve showing per cent true watts
recorded with varying load, 100 %
normal voltage, normal frequency
Run No 3

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.



Sangamo Meter No. 7661
Curves showing per cent true watts
recorded with varying power factor, constant
full load current, normal voltage, normal
frequency
I – Run No 4 – Experimental
II – No 5 – Calculated

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.



Sangamo Meter No. [illegible]
Curves showing % true watts recorded
with varying volts
I – Run No. 6 – normal voltage, normal frequency, [illegible]
II – Run No. 7 – [illegible]

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

General Electric Meter # 1506564.

Resistance of 60 cycle pressure coil .... 679.5 ohms.
" " 25 " " " .... 132.5 " .
" " 10 ampere series coil .... .027 ohms.

Data for the determination of the phase relation of the series and pressure fluxes.

Volts 110. Amperes 10. Apparent Watts 1100.

Direction of Rotation of Disc.	Dynamometer Reading.	True Watts.	Cos θ.
Forward	-19	34	.0309
Backward	+2	4.5	.0041
Forward	-21	38	.0345
Backward	+2	4.5	.0041
Forward	-18.5	33	.0300
Backward	+2	4.5	.0041

Average cos θ for forward rotation .... .0318
" θ " " " .... 88° 10'
" cos θ " backward " .... .0041
" θ " " " .... 90° 13'
Phase angle from quadrature for forward rotation 13'
" " " " " backward " 1° 50'
Average phase angle from quadrature .... 48.5'
Phase difference between series and pressure fluxes 90° 48.5'

General Electric Meter # 1506564.

Run # 1.

Data showing the effect of change of load with unity power factor, 100 % normal voltage, and normal frequency.

110 volts. 60 cycles. Temperature 73 F.

Watts	Watt hours Recorded.	T	True Watt hours	% Recorded
120	3	106.5	3.54	85.
325	10	116.0	10.46	95.8
545	20	134.5	20.35	98.4
825	27	119.0	27.25	99.0
1050	35	120.0	35.00	100.0
1279	45	127.0	45.00	100.0
1440	45	114.0	45.70	98.7

T is the time in seconds.

General Electric Meter # 1506564.

Run # 2.

Data showing the effect of change of load with unity power factor, normal frequency, and 109 % normal voltage.

120 volts. 60 cycles. Temperature 73 F.

Watts	Watt hours Recorded.	T	True Watt hours	% Recorded.
145	4	116	4.67	85.7
333	11	123	11.40	97.0
602	19	113	18.90	100.5
885	28	114	27.7	100.2
1203	38	113.7	38.00	100.0
1523	47	112.5	47.60	99.0
1800	54	111.4	55.70	99.0

T is the duration of each run in seconds.

General Electric Meter # 1506564.

Run # 3.

Data showing the relation between the load and the % of true watt hours recorded with varying load ,normal frequency, unity power factor, and 91 % normal voltage.

100 volts. 60 cycles. Temperature 73 F.

Watts	Watt hours Recorded	T	True Watt hours.	% Recorded.
105	3	126.5	3.69	81.4
350	10	116.0	11.3	88.5
490	16	119.0	16.2	98.8
773	26	121.0	26.0	100.0
990	32	114.3	31.4	101.8
1145	36	113.3	36.0	100.0
1370	42	111.7	42.2	99.8
1560	50	116.0	50.4	99.3

T is the time in seconds.

General Electric Meter # 1506564.

Run # 4.

Data showing the relation between the load and the % of true watts recorded with normal frequency, unity power factor, and 100 % normal voltage.

110 volts. 25 cycles Temperature 73 F.

Watts	Watt hours Recorded.	T	True Watt hours	% Recorded.
120	3	104.0	3.46	86.8
335	9	101.0	9.4	95.8
545	19	128.0	19.4	98.0
833	25	109.0	25.2	99.3
1050	30	104.0	30.4	98.8
1283	43	122.0	43.5	98.8
1460	47	117.5	47.8	98.4
1675	47	104.0	48.4	97.2

T is the time in seconds.

General Electric Meter # 1506564.

Run # 5

Data showing the effect of change of power factor with constant full load current, normal frequency, and normal voltage.

110 volts. 10 amperes. 60 cycles Temperature 75 F.

Cos θ	Watt hours Recorded.	T	True Watt hours	% Recorded.
1.000	35	114.5	35	100
.981	37	124	37.2	99.5
.855	35	136	35.5	98.6
.781	30	127	30.4	98.5
.691	25	120	25.4	98.4
.622	24	129.5	24.62	97.3
.536	20	129	21.1	95.0

T is the duration of each run in seconds.

General Electric Meter #1506564.

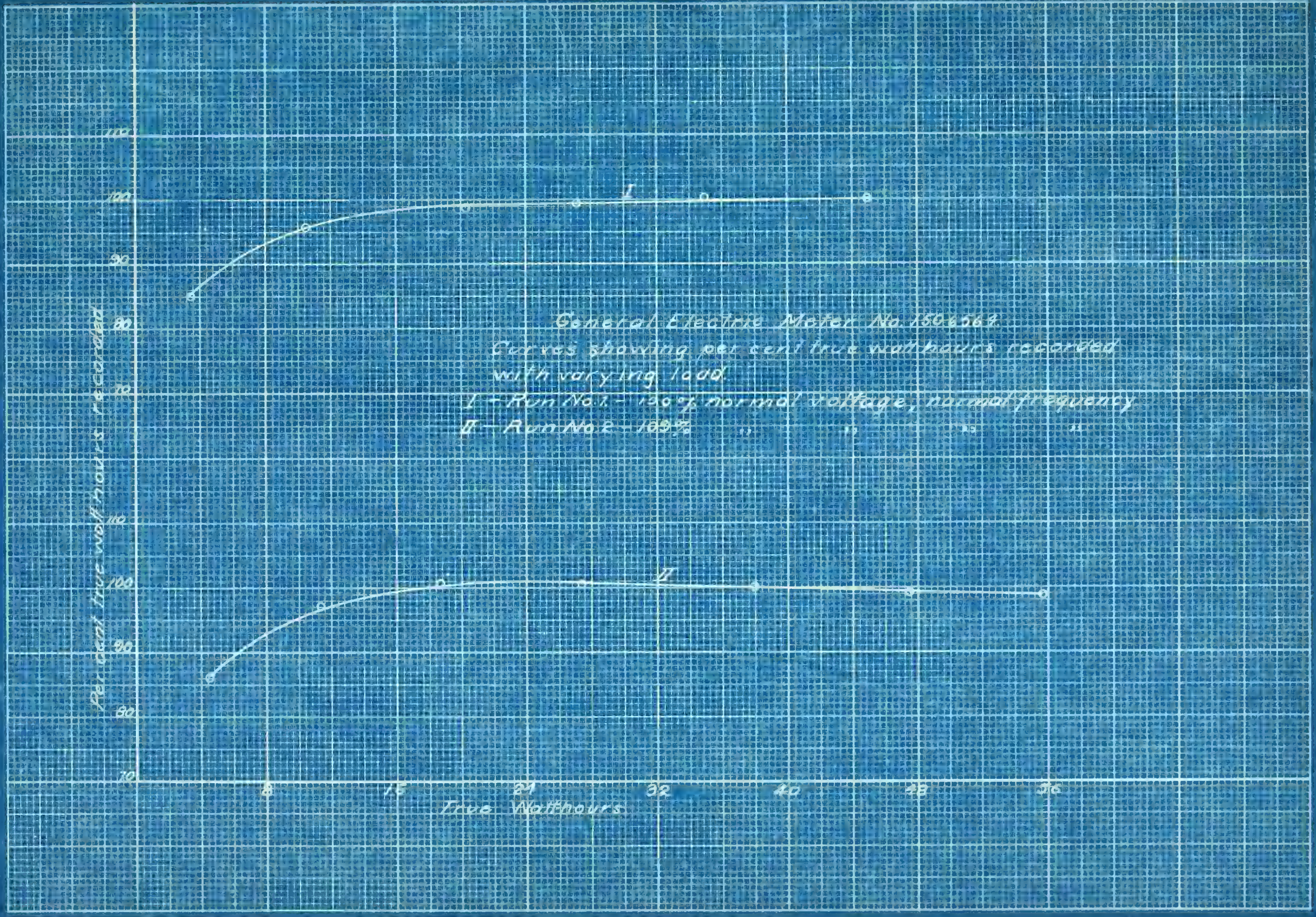
#6.

Data, calculated from the flux quadrature determination, showing the effect of change of power factor with constant full load current, normal frequency and normal voltage.

110 volts. 10 amperes. 60 cycles.

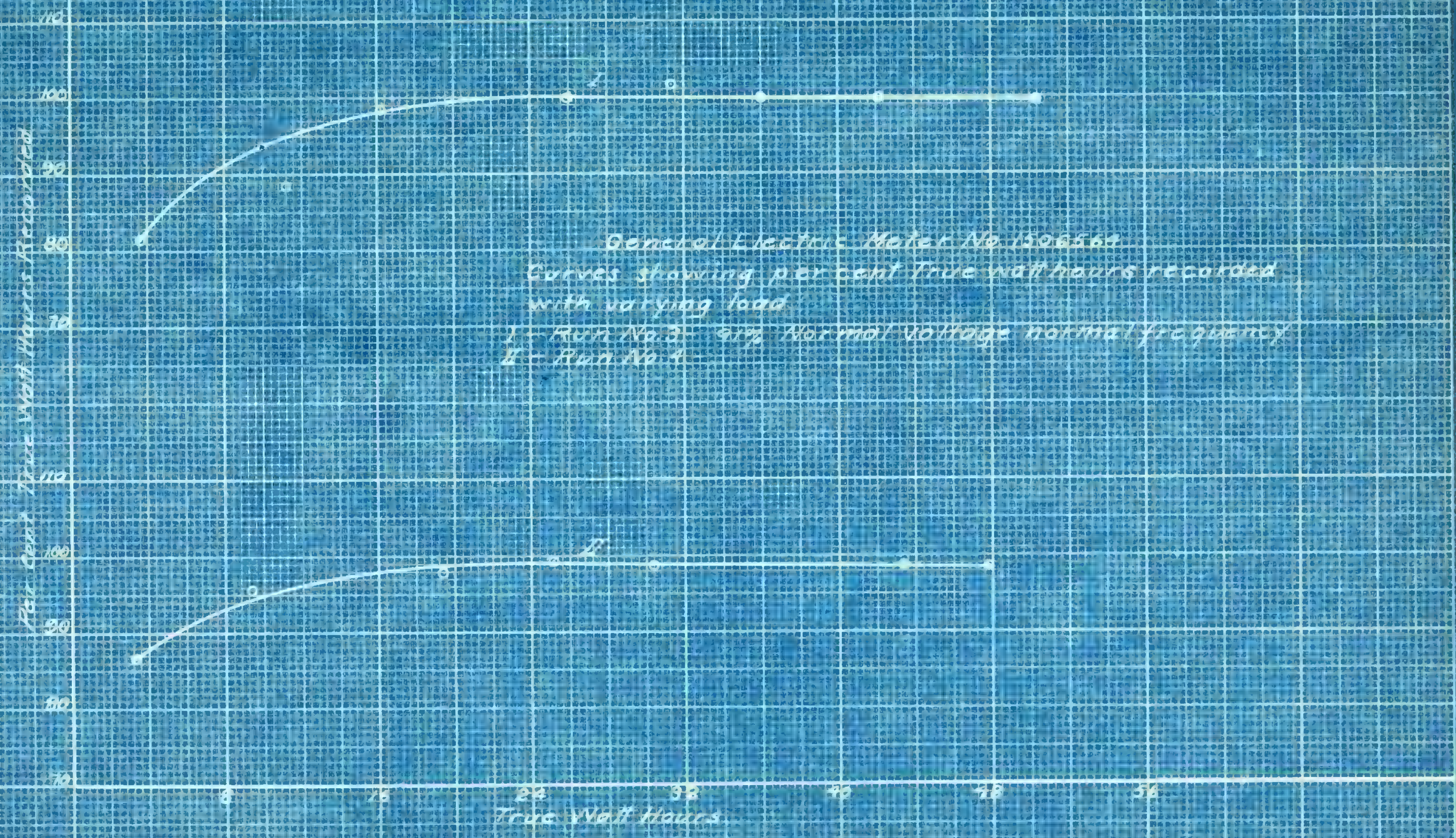
Cos θ.	True Watts.	Watts Recorded.	% Recorded.
1.0000	1100	1100	100.0
.9396	1032	1028	99.6
.8660	954	946	99.3
.7660	844	834	98.7
.6428	707	695	98.3
.5735	631	618	98.0
.5000	550	538	97.6

EUGENE DIETZGEN CO, CHICAGO-NEW YORK



General Electric Meter No. 1506564
Curves showing per cent true watthours recorded
with varying load
I – Run No. 1 – 130% normal voltage, normal frequency
II – Run No. 2 – 105% " " "

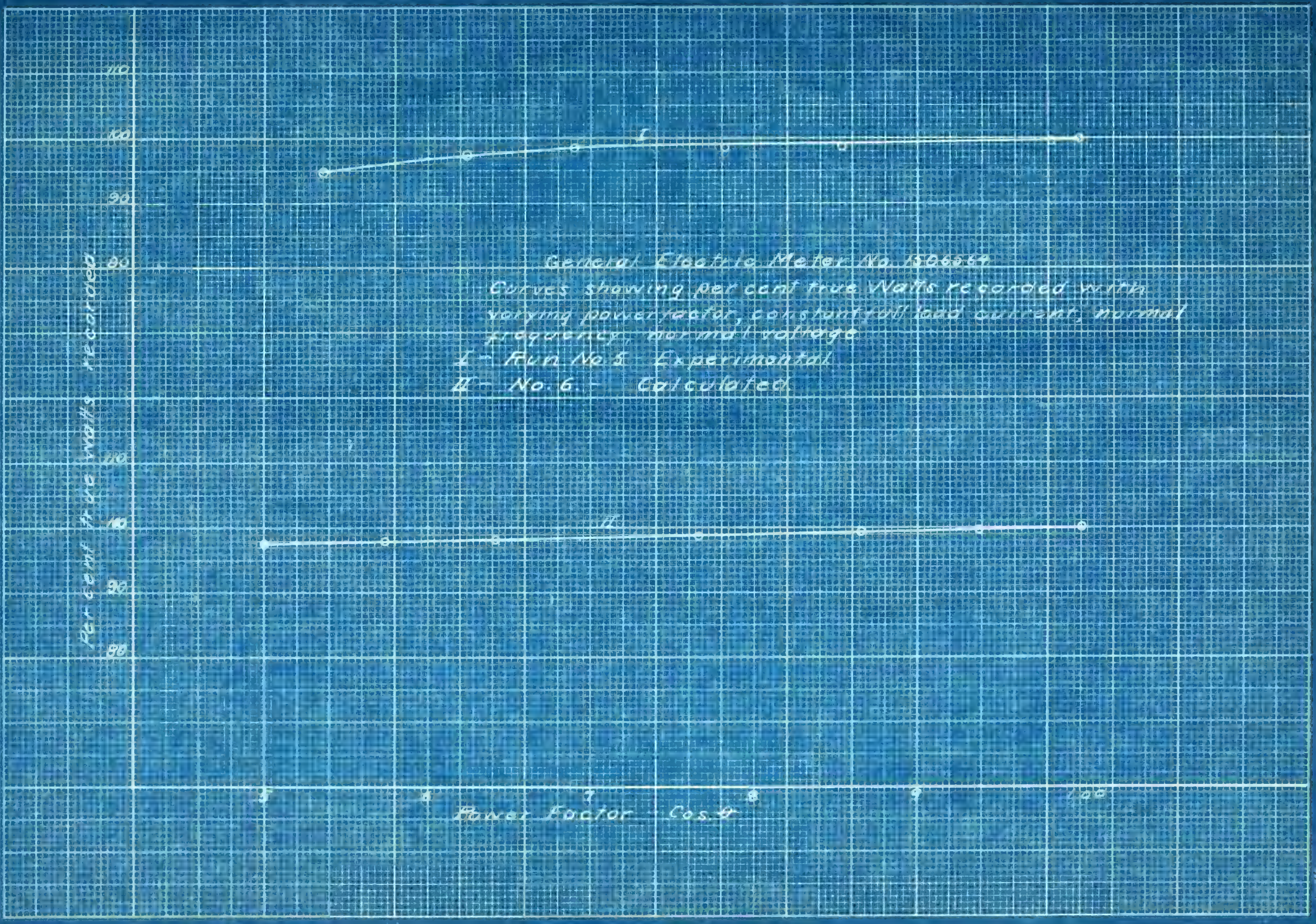
ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.



General Electric Meter No 1506564
Curves showing per cent True watt hours recorded
with varying load
I – Run No 3 – 97% Normal voltage normal frequency
II – Run No 4

EUGENE DIETZGEN CO. CHICAGO-NEW YORK

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.



General Electric Meter No. 1506564

Curves showing per cent true Watts recorded with varying power factor, constant full load current, normal frequency, normal voltage

I – Run No. 5. Experimental

II – No. 6. – Calculated

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

Westinghouse Meter # 681372.

Resistance of pressure coil .... 427 ohms.

" " series " .... .0775 ohms.

Data for the determination of the phase relation of the series and pressure fluxes.

Volts 100 Amperes 5 Apparent Watts 500.

Direction of Rotation of Disc.	Dynamometer Reading.	True Watts	Cos θ.
Forward	4	8	.016
"	5	10	.020
"	4.5	9	.018
Backward	0	1	.0002
"	0	1	.0002
"	1	2.5	.0050

Average cos θ for forward rotation .... .018

" θ " " " .... 88° 58'

" cos θ " backward " .... .0018

" θ " " " .... 89° 54'

Phase angle from quadrature for forward rotation 1° 2'

" " " " " backward " 6'

Average phase angle from quadrature .... 34'

Phase angle between series and pressure fluxes .. 90° 34'

Westinghouse Meter # 681372

Run # 1.

Data showing the effect of change of load with unity power factor, normal voltage, and normal frequency.

100 volts. 60 cycles. Temperature 82 F

Current	True Watts	R	T	Watts Recorded	% Recorded
1.00	100	6	98.3	73.3	73.3
1.45	140	11	111.	119.	85.0
1.88	210	18	111.	195.	92.8
3.12	314	29	114.	306.	97.4
4.15	415	36	105.	412	99.4
5.00	500 ~~480~~	48	114	505	101.0
6.20	620	61	119	616	99.5
7.50	735	71	116	735	100.0

R is the no. of revolutions made by the disc in T seconds.

Westinghouse Meter # 681372

Run # 2

Data showing the effect of change of load with unity power factor,110% voltage ,and normal frequency.

110 volts 60 cycles Temperature 82 F

Current	True Watts	R	T	Watts Recorded	% Recorded
.90	100	7	99.2	77.8	77.8
1.20	130	10	115.3	114.5	88.0
2.25	240	22	1132	233.0	94
3.05	335	30	109.6	328	97.7
4.05	444	40	109.3	440	99.2
5.00	550	53	115	554	100.5
6.40	700	67	115.3	697	99.5
7.40	800	79	116.7	814	100

R is the no. of revolutions made by the disc in T seconds.

Westinghouse Meter #681372.

Run # 3

Data showing the effect of change of load with unity power factor, 90% normal voltage, and normal frequency.

90 volts 60 cycles Temperature 82 F

Current	True Watts	R	T	Watts Recorded	% Recorded
1.00	90	7	119	70.5	78.4
1.35	125	12	119	121.0	84.0
2.30	210	19	116	196	93.5
3.45	315	28	110.5	302	96.5
4.30	395	36	110.3	372	99.3
5.50	500	48	114	506	101.0
6.60	595	50	105.4	570	99.3
7.60	690	65	114	685	99.2

R is the no. of revolutions made by the disc in T seconds.

Westinghouse Meter # 681372.

Run # 4

Data showing the effect of change of load with unity power factor, normal voltage, and 25 cycles.

100 volts 25 cycles. Temperature 82 F.

Current	True Watts	R	T	Watts Recorded	% Recorded.
1.10	115	7	86	97.7	85.
2.25	227	18	104.5	203.8	94.8
3.17	315	27	104.5	310.0	98.4
4.10	410	35	103.	407.0	99.2
5.20	520	44	101.5	520.0	100.0
6.40	646	55	102.5	645.0	100.0
7.60	760	70	110.5	760.0	100.0

R is the no. of revolutions made by the disc in T seconds.

Westinghouse Meter # 681372.

Run # 5

Data showing the effect of change of power factor with normal voltage, normal frequency, and 100 % load.

100 volts. 5 amperes. 60 cycles. Temperature 74 F

Cos θ	True Watts	R	T	Watts Recorded	% Recorded.
.94	470	46	118.2	475	101.
.84	420	38	108.0	422	100.3
.76	380	38	100.5	382	100.5
.67	335	30	109.0	330	98.5
.58	290	25	107.0	281.5	97.0

R is the no. of revolutions made by the disc in T seconds.

Westinghouse Meter # 681372.

6

Data, calculated from the flux quadrature determination, showing the effect of change of power factor with constant full load, normal voltage, and normal frequency.

100 volts. 5amperes. 60 cycles. Temperature

Cos θ	True Watts	Watts Recorded	% Recorded
1.0000	500	500	100.
.9397	470	468	99.6
.8660	433	431	99.4
.7660	383	380	99.3
.6428	322	318	99.0
.5000	250	245.8	98.3

Westinghouse Meter # 681372.

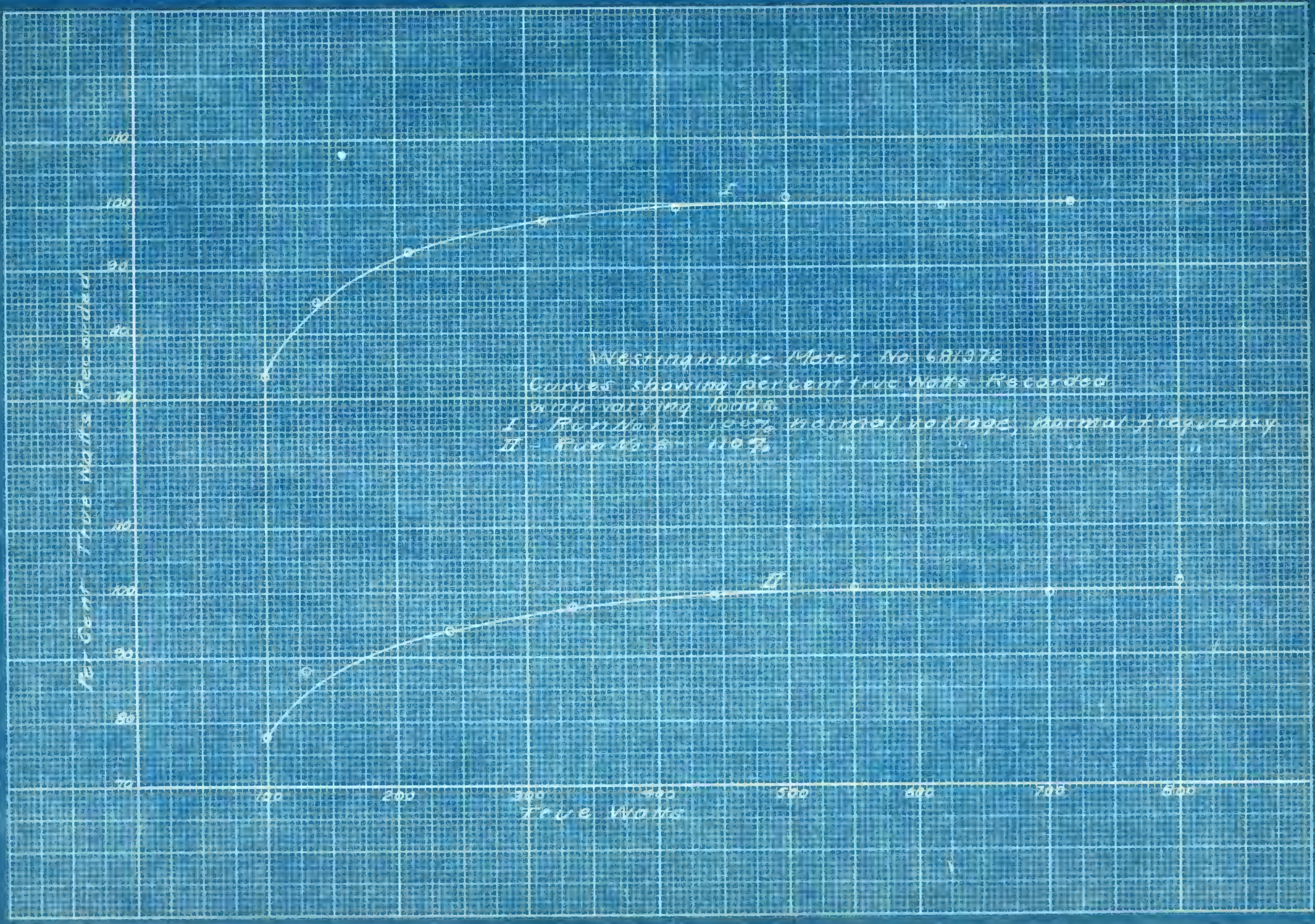
Run # 7.

Data showing the relation between the load and the % of true watts recorded with unity power factor, normal voltage, and a frequency of 120 cycles.

110 volts. 120 cycles. Temperature 70 F.

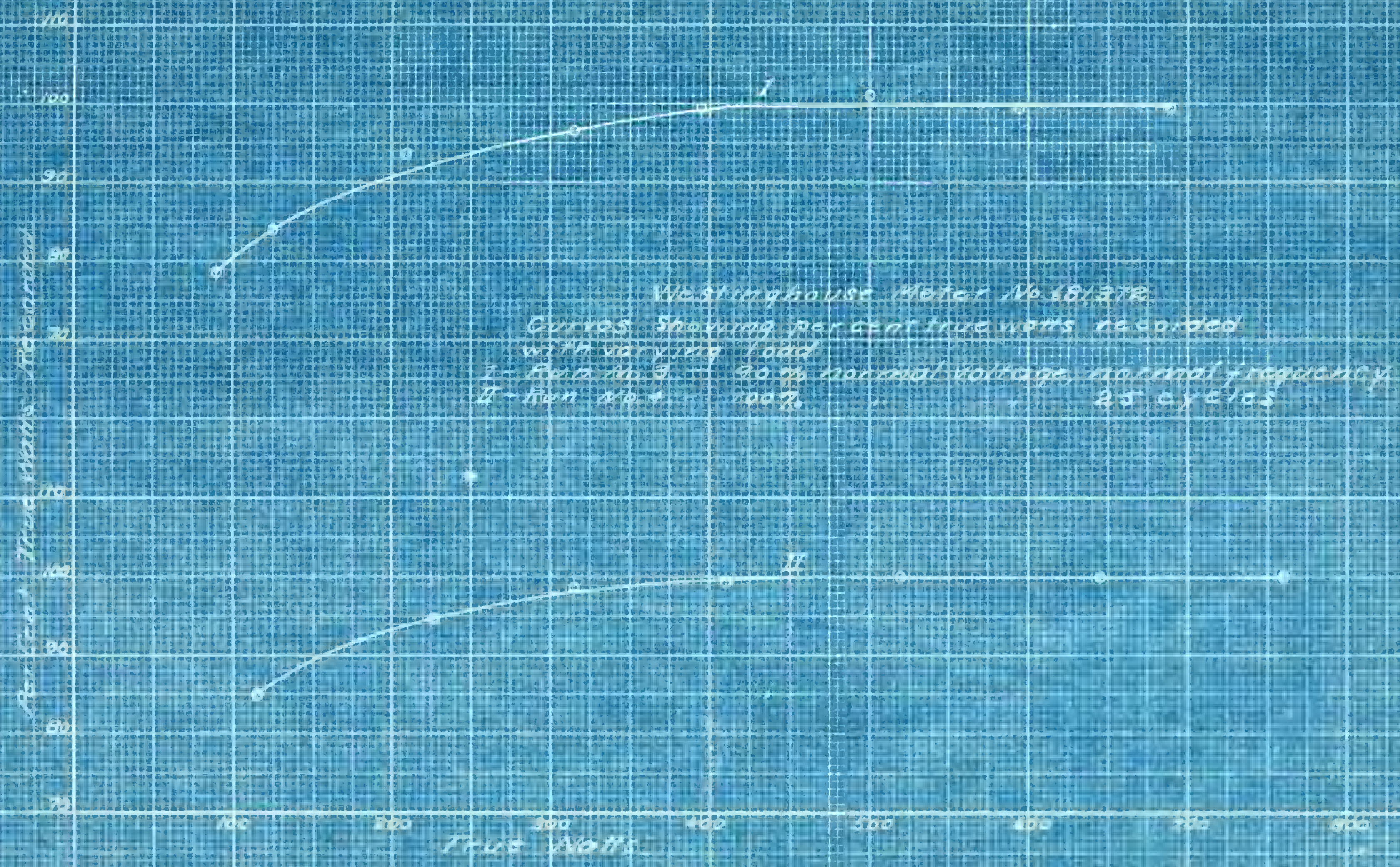
Current	True Watts	R.	T.	Watts Recorded.	% Recorded.
1.15	125	10	105	114.2	91.5
2.14	235	20	108	220	94.5
3.45	380	28	89	378	99.4
5.00	550	36	120.6	558	101.4
6.50	715	57	95	720	102.0

R is the no. of revolutions made by the disc in T seconds.



Westinghouse Meter No 681978
Curves showing per cent true Watts Recorded
with varying loads.
I – Running 100% normal voltage, normal frequency
II – Running 110% " "

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.



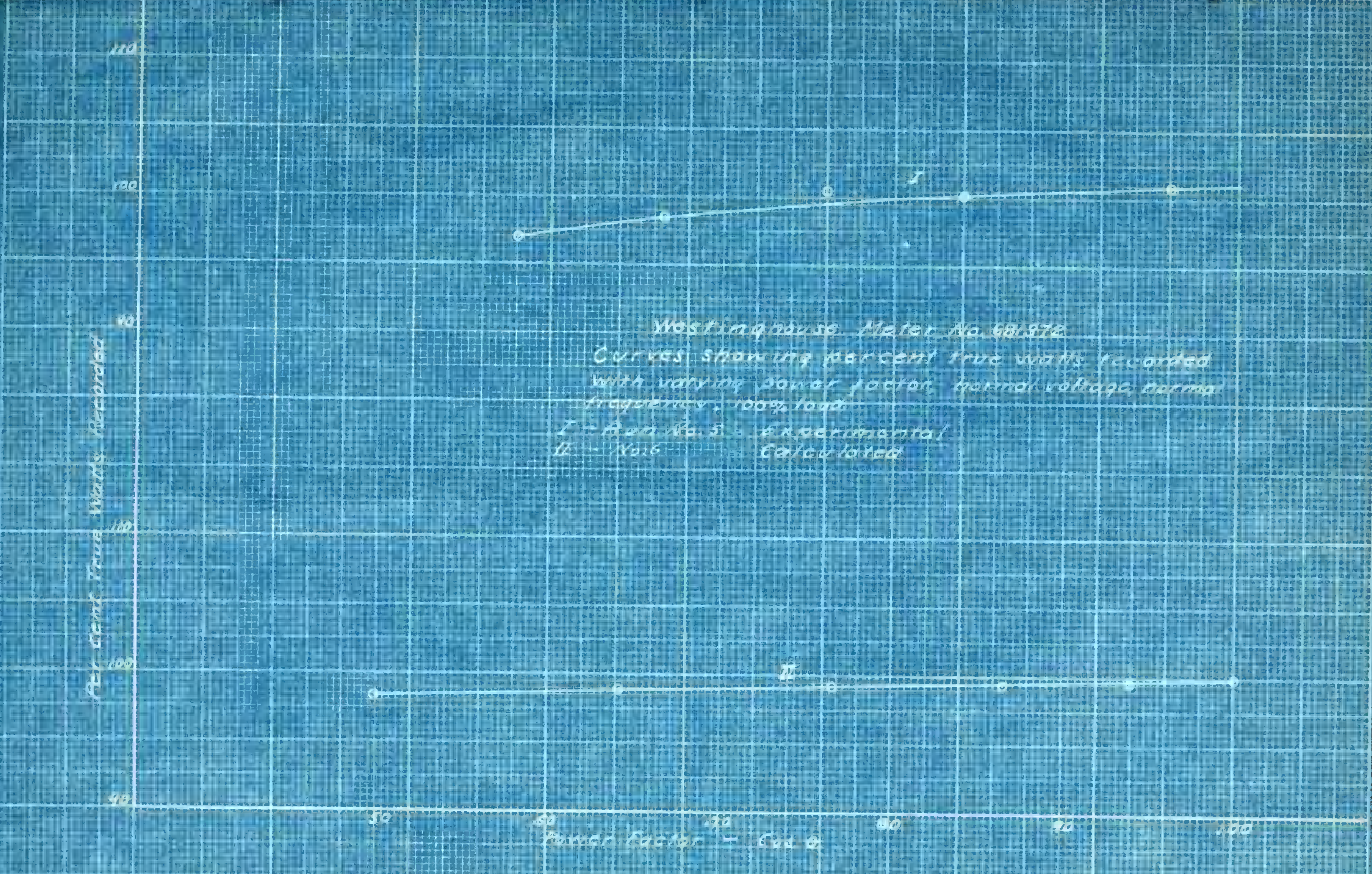
Westinghouse Meter No 181378

Curves Showing per cent true watts recorded with varying load

I - Run No 3 — 90 % normal voltage normal frequency

II - Run No 4 — 100 % " " 25 cycles

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.


Westinghouse Meter No. 68972

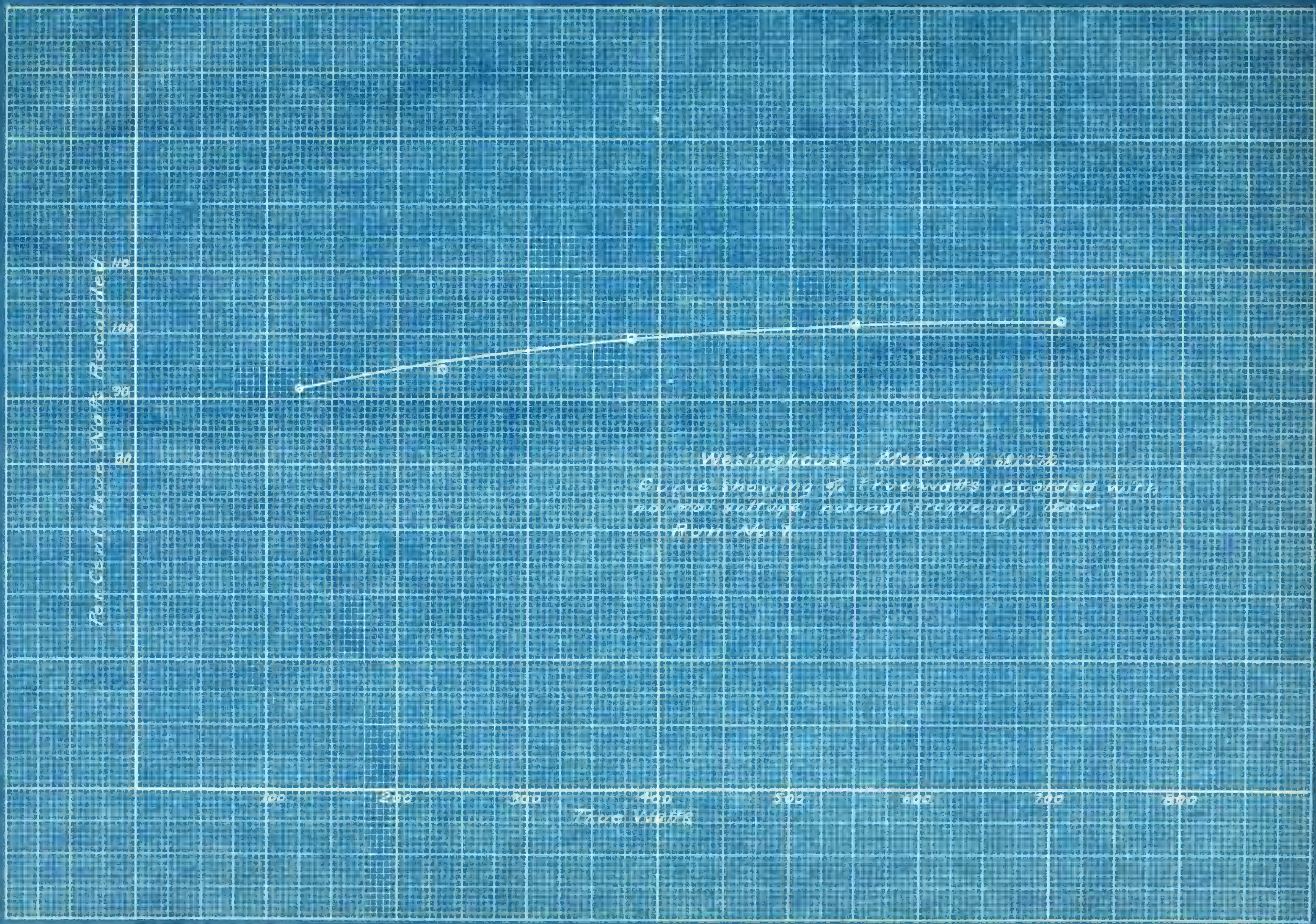
Curves showing percent true watts recorded with varying power factor, normal voltage, normal frequency, 100% load.

I – Run No. 5 Experimental

II – No. 6 Calculated

EUGENE DIETZGEN CO. CHICAGO–NEW YORK

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.


Westinghouse Meter No 60332
Curve showing % true watts recorded with
normal voltage, normal frequency, 60~
Run No 1
Per Cent True Watts Recorded
80
90
100
110
True Watts
100
200
300
400
500
600
700
800

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.

Duncan Meter # 61666.

Resistance of pressure coil .... 2780. ohms.
" " series " .... .0575 ohms.

Data for the determination of the phase relation of the series and pressure fluxes.

Volts 110 Amperes 10 Apparent Watts 1100.

Direction of Rotation of Disc.	Dynamometer Reading.	True Watts	Cos θ.
Forward	-24	42	.0382
"	-22	40	.0364
"	-26	44	.0400
Backward	+ 2	4	.00364
"	+ 2	4	.00364
"	+ 2	4	.00364

Average cos θ for forward rotation .... .0382
" θ " " " .... 87° 49'
" cos θ " backward " .... .00364
" θ " " " .... 90° 13'

Phase angle from quadrature for forward rotation 2° 11'
" " " " " backward " 13'

Average phase angle from quadrature .... 59'

Phase difference between series and pressure fluxes 59'.

Duncan Meter # 61666.

Run # 1.

Data showing the effect of change of load with unity power factor, 100 % normal voltage, and normal frequency.

110 volts. 60 cycles. Temperature 84 F.

Current	True Watts.	R	T	Watts Recorded	% Recorded.
1.05	115	6	121	89.5	78.0
3.50	385	24	124.5	345.	90.0
5.05	555	35	117.	505.	91.0
8.50	935	60	116.	932.	99.7
11.50	1262	84	120.	1260	99.9
13.25	1465	100	121.	1490	101.8
15.30	1690	115	120.5	1720	102.0

R is the no. of revolutions made by the disc in T seconds.

Duncan Meter #61666.

Run # 2.

Data showing the effect of change of load with unity power factor, 91 % normal voltage, and normal frequency.

100 volts. 60 cycles. Temperature 84 F.

Current	True Watts	R	T	Watts Recorded	% Recorded.
1.54	155	8	120	120	77.5
3.15	316	20	120	300	95.0
4.90	490	30	113	478	97.5
7.50	750	50	119	757	101.0
9.70	973	70	127	992	102.0
13.50	1345	93	122.5	1366	101.5
15.60	1565	108	122	1595	101.8

R is the no. of revolutions made by the disc in T seconds.

Duncan Meter # 61666.

Run # 3.

Data showing the effect of change of load with unity power factor, 109 % normal voltage, and normal frequency.

120 volts. 60 cycles. Temperature 84 F

Current	True Watts	R	T	Watts Recorded	% Recorded.
1.20	145	7	110	115	79.0
3.20	385	23	115	360	93.6
5.00	600	36	112	578	96.3
7.60	910	57	113	910	100.0
9.40	1125	71	115	1111	99.0
11.30	1366	95	124.5	1372	100.4
13.60	1630	105	117	1615	99.2
15.50	1880	123	119	1860	99.0

R is the no. of revolutions made by the disc in T seconds.

Duncan Meter # 61666.

Run # 4

Data showing the effect of change of power factor with constant full load, 100 % normal voltage, and normal frequency.

110 volts. 10.1 amperes. 60 cycles Temperature 84 F

Cos.θ.	True Watts.	R	T	Watts Recorded	% Recorded.
.965	1065	38	65	1052	99.0
.914	1005	35	63	1000	99.0
.838	932	33	64	928	99.6
.770	854	30	64	845	99.0
.657	730	25	63.5	710	97.3
.517	574	21	69	548	96.5

R is the no. of revolutions made by the disc in T seconds.

Duncan Meter # 61666.

Run # 5

Data showing the effect of change of load with unity power factor, 100 % normal voltage, and 25 cycles.

110 volts. 25 cycles. Temperature 80 F.

Current.	True Watts.	R	T	Watts Recorded	% Recorded.
1.1	120	4	71	101.2	84.5
3.45	382	12	60	360.	94.3
5.20	570	19	61.6	556.	97.2
7.55	832	27	60	811.	97.7
10.22	1115	37	59.7	1115.	100.0
12.70	1400	47	60	1410.	100.7
14.95	1650	55	60.3	1640	99.5

R is the no. of revolutions made by the disc in T seconds.

Duncan Meter # 61666.

Run # 6.

Data showing the effect of change of load with unity power factor, normal voltage, and 120 cycles.

110 volts. 120 cycles. Temperature 77 F.

Current	True Watts	R	T	Watts Recorded.	% Recorded.
1.1	120	6	114.5	94.5	78.6
2.1	228	12	108.	200.	87.8
3.75	422	24	107.	404.	95.8
5.2	574	35	113.	558	97.3
7.8	788	50	116.	777	98.6
10.2	1125	71	117	1100.	97.0
12.3	1350	86	118	1312.	97.2
14.9	1640	101	116	1565.	95.5

R is the no. of revolutions made by the disc in T seconds.

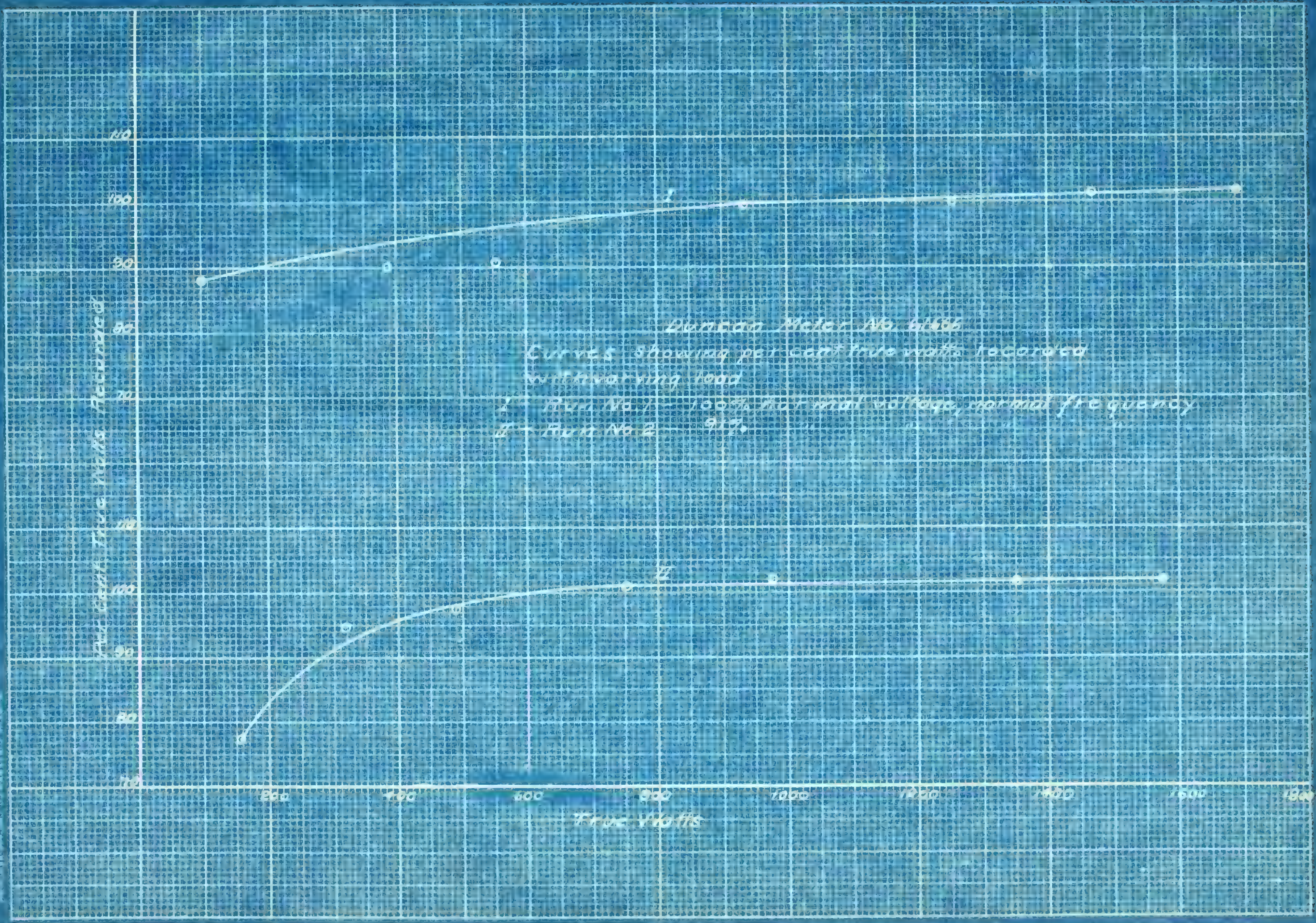
Duncan Meter # 61666.

7.

Data calculated from the flux phase determination showing the effect of change of power factor with normal frequency, normal voltage, and constant full load current.

Volts 110 Amperes 10 Cycles 60.

Cos θ	True Watts	Watts Recorded	% Recorded.
1.000	1100	1100	100.0
.966	1061	1057	99.6
.866	953	944	99.1
.766	844	831	98.5
.656	723	708	98.0
.500	550	534	97.2

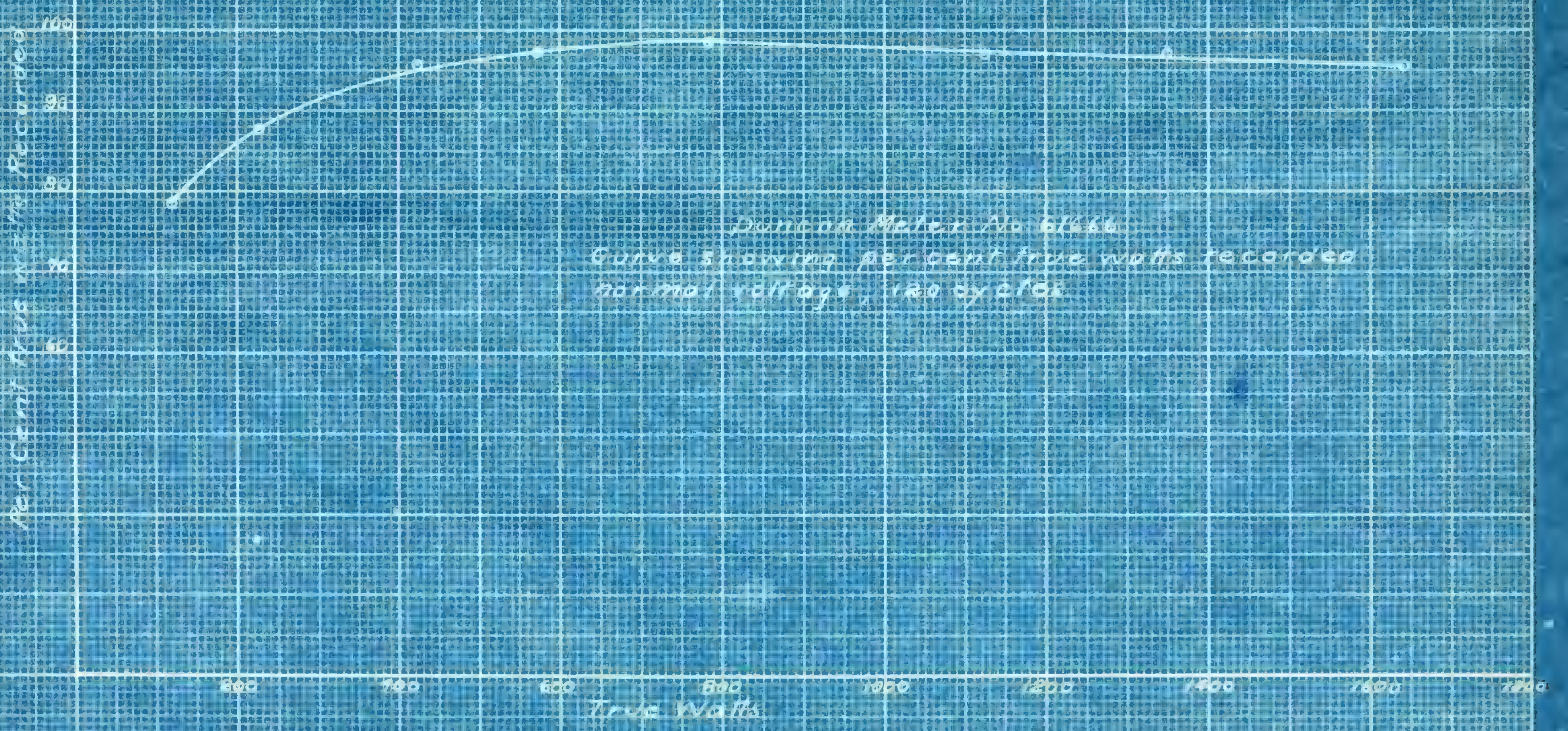

Duncan Meter No. 6406

Curves showing per cent true watts recorded with varying load

1 — Run No. 1 — 100% normal voltage, normal frequency

2 — Run No. 2 — 91%

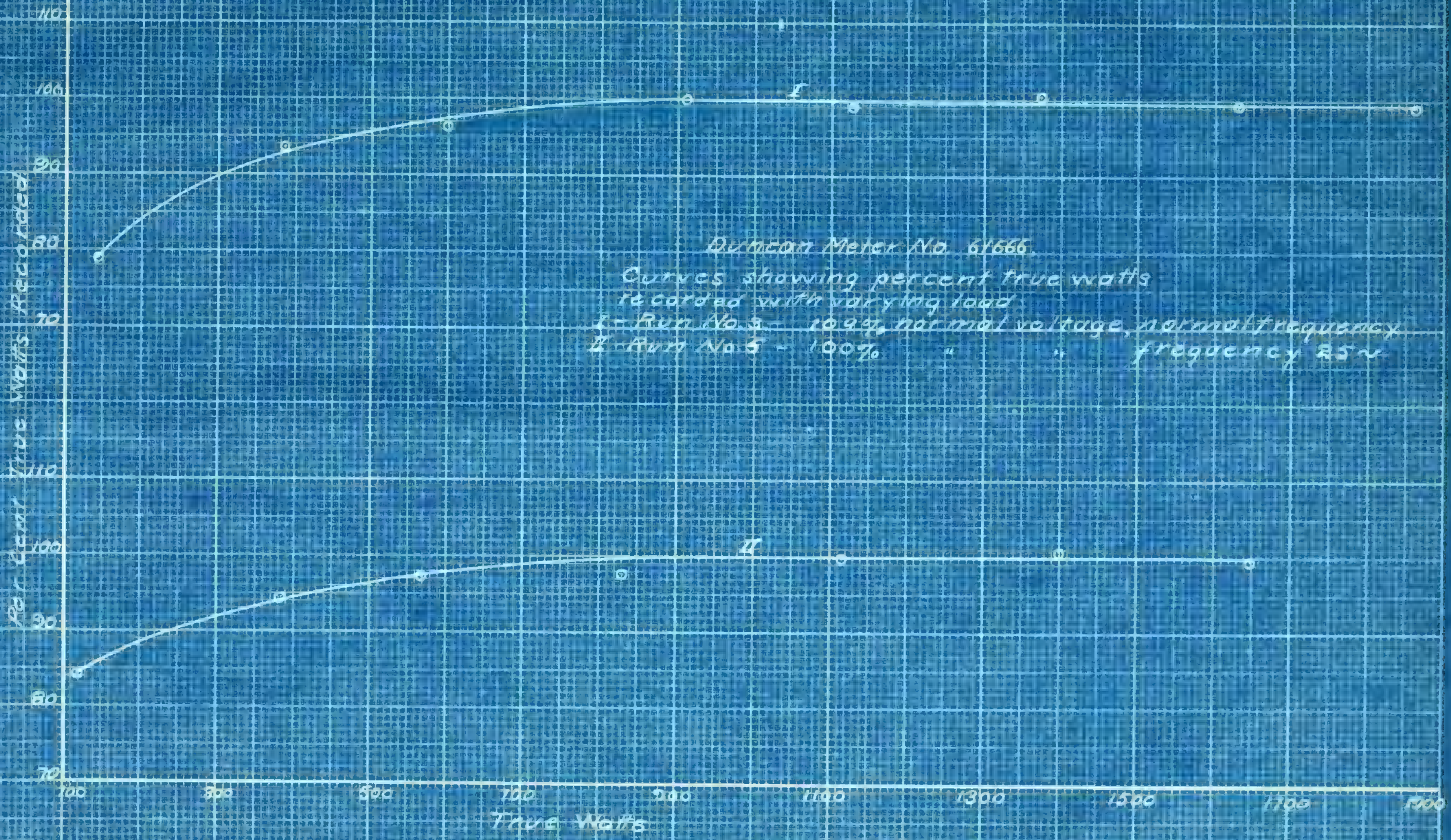
ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.



Duncan Meter No. 61666.
Curve showing percent true watts recorded
normal voltage, 130 cycles

EUGENE DIETZGEN CO. CHICAGO-NEW YORK

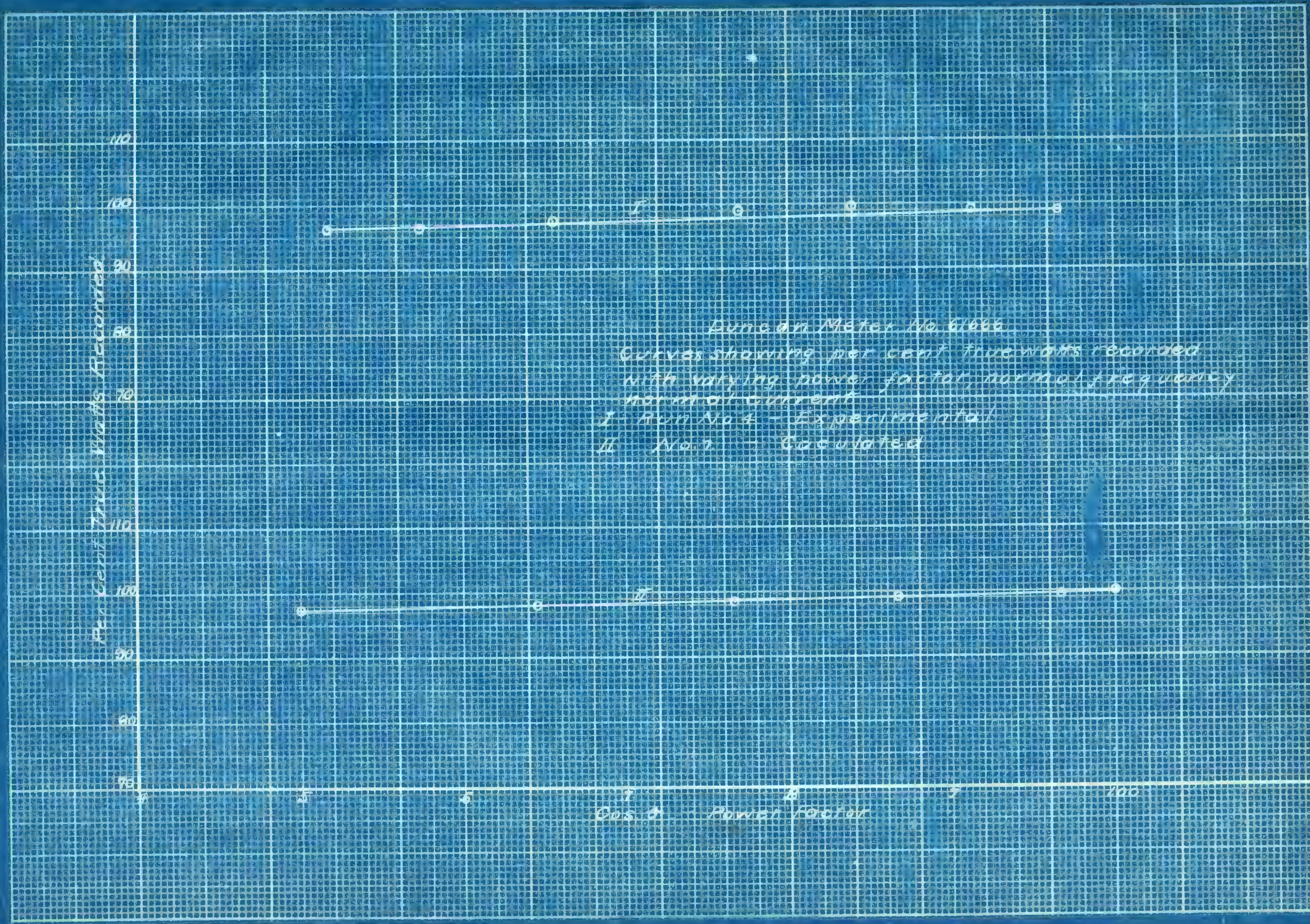
ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.



Duncan Meter No. 61666.

Curves showing percent true watts
recorded with varying load
I – Run No 3 – 109% normal voltage, normal frequency
II – Run No 5 – 100% " " frequency 25~

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.


Duncan Meter No 6166
Curves showing per cent true watts recorded
with varying power factor, normal frequency
normal current
I Run No 4 - Experimental
II No 7 Calculated
I
II
Per Cent True Watts Recorded
110
100
90
80
70
110
100
90
80
70
4
5
6
7
8
9
100
Cos θ Power factor
EUGENE DIETZGEN CO. CHICAGO-NEW YORK

GEORGIA
INSTITUTE OF TECHNOLOGY
LIBRARY.

Duncan Meter # 74520.

Resistance of pressure coil .... 2295. ohms.

" " series " .... .0875 ohms.

Data for the determination of the phase relation of the series and pressure fluxes.

Volts 110. Amperes 10. Apparent Watts 1100.

Direction of Rotation of Disc.	Dynamometer Reading.	True Watts	Cos θ.
Forward	−13	24	.0218
"	−12	22	.0200
"	−12.5	23	.0209
Backward	+4	8	.00726
"	+4	8	.00726
"	+4	8	.00726

Average cos θ for forward rotation	.0209
" θ " " "	88° 48'
" cos θ " backward "	.00726
" θ " " "	90° 25'
Phase angle from quadrature for forward rotation	1° 12'
" " " " " backward "	25'
Average phase angle from quadrature	23.5'
Phase angle between series and pressure fluxes .	23.5'

Duncan Meter # 74520

Run # 1

Data showing the effect of change of load with unity power factor, 100 % normal voltage, and normal frequency.

110 volts.   60 cycles.   Temperature 73 F.

Current.	True Watts	R.	T	Watts Recorded	% Recorded.
1.55	173	8	118.7	122	70.5
3.00	328	20	128.	281	85.8
5.20	573	35	118.	534	92.0
7.95	875	57	121.2	848	96.8
10.85	1195	79	121.5	1170	98.0
13.25	1455	97	121.5	1435	98.5
15.50	1700	113	120.8	1685	99.0

R is the no. of revolutions made by the disc in T seconds.

Duncan Meter # 74520.

Run # 2.

Data showing the effect of change of load withunity power factor, 109 % normal voltage, and normal frequency.

120 volts. 60 cycles. Temperature 73 F

Current	True Watts	R	T	Watts Recorded	% Recorded.
1.10	130	7	128.5	98.5	77.0
3.25	388	22	122.7	323.0	83.2
4.85	585	36	122.	531.	90.5
8.10	970	62	121.6	918.	94.7
10.50	1258	81	119.	1225	97.4
13.10	1570	100	116.	1550	98.8
15.50	1850	122	120	1830	99.0

R is the no. of revolutions made by the disc in T seconds.

Duncan Meter # 74520.

Run # 3.

Data showing the effect of change of load with unity power factor, 91% normal voltage, and normal frequency.

100 volts. 60 cycles. Temperature 73 F.

Current	True Watts	R	T	Watts Recorded	% Recorded.
1.35	140	6	123.7	87.3	62.3
3.15	315	17	113.	271.	86.0
4.93	495	28	111.2	453.	91.5
9.40	940	57	112.	916.	97.5
11.50	1140	69	112.	1110	97.5
13.00	1298	78	109.2	1286	99.0
15.00	1510	90	108.5	1495	99.1

R is the no. of revolutions made by the disc in T seconds.

Duncan Meter # 74520.

Run #4.

Data showing the effect of change of load with unity power factor, 100 % normal voltage, and 25 cycles.

110 volts. 25 cycles. Temperature 80.F.

Current.	True Watts.	R	T	Watts Recorded	% Recorded.
1.1	120	3	59	91.5	76.1
3.15	345	11	62.8	315.	91.4
5.75	628	20	60	600	97.0
7.75	848	28	61.2	826	97.5
10.15	1115	38	62.	1105	99.5
12.90	1420	47	60.3	1405	99.0
15.00	1650	55	60.5	1635	99.0

R is the no. of revolutions made by the disc in T seconds.

Duncan Meter # 74520.

Run # 5.

Data showing the effect of change of power factor with constant full load current, normal frequency, and normal voltage.

110 volts. 10 amperes. 60 cycles. Temperature 75 F.

Cos θ.	True Watts	R	T	Watts Recorded	% Recorded.
1.000	1110	38	61.8	1115	100.5
.945	1040	58	100.0	1045	100.5
.880	970	65	120.5	970	100.0
.764	840	48	102.0	846	100.7
.710	780	46	104.0	790	101.0
.595	655	41	111.5	660	100.8
.517	570	32	100.0	576	101.0

R is the no. of revolutions made by the disc in T seconds.

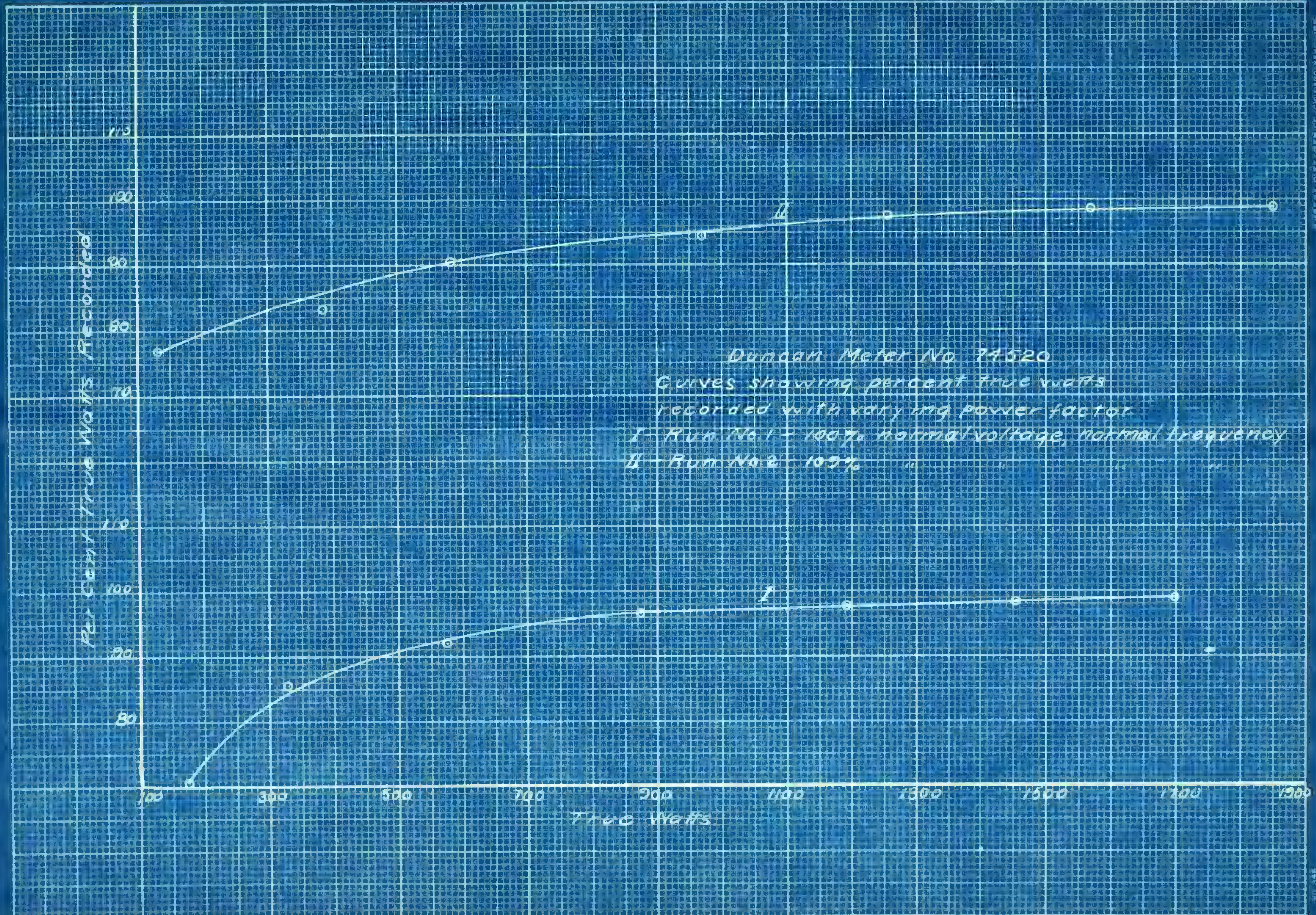
Duncan Meter # 74520.

6

Data calculated from the flux phase determination showing the effect of change of power factor with normal frequency, normal voltage, and constant full load current.

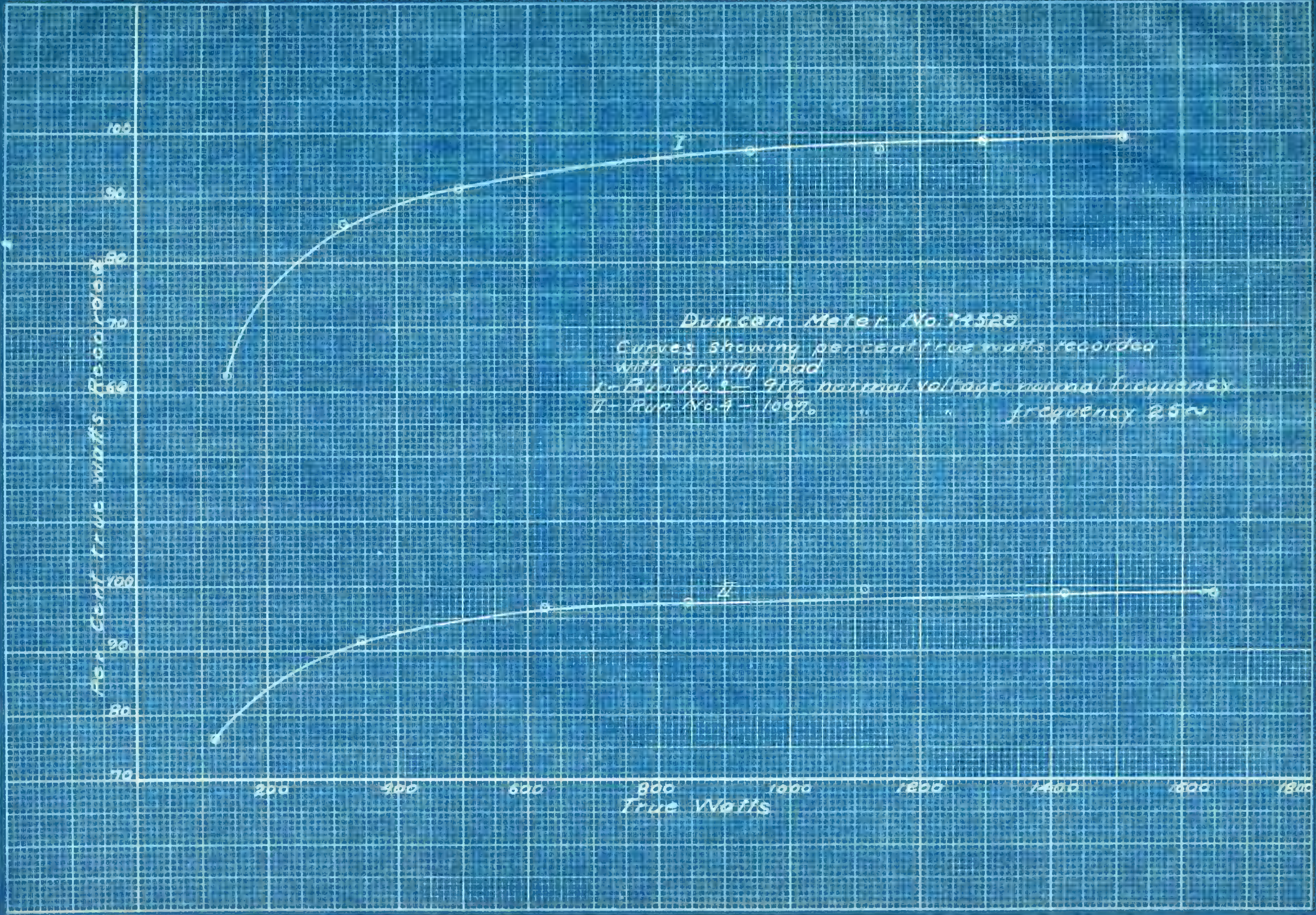
Volts 110 Amperes 10 Cycles 60

Cos θ.	True Watts	Watts Recorded.	% Recorded
1.000	1100	1100	100
.966	1061	1062	100.1
.866	954	957	100.3
.766	844	848	100.5
.642	707	714	100.8
.500	550	557	101.1



Duncan Meter No. 74520
Curves showing percent true watts
recorded with varying power factor
I Run No 1 – 100% normal voltage, normal frequency
II Run No 2 – 105% " " " "

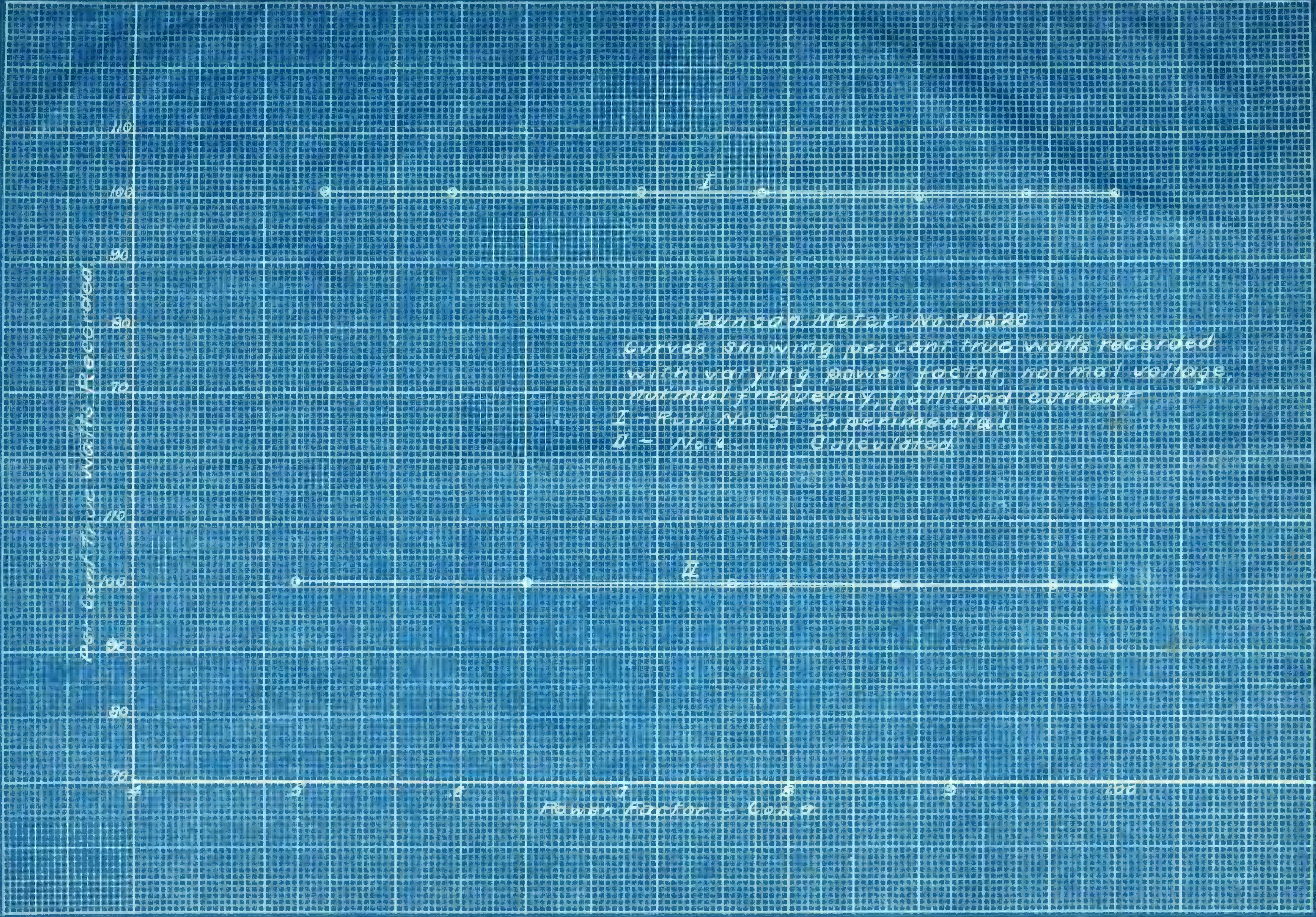
ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.



Duncan Meter No. 74520

Curves showing per cent true watts recorded
with varying load
I - Run No. 3 — 91% normal voltage, normal frequency
II - Run No. 4 - 100% " " frequency 25~

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.



Duncan Meter No 74620
Curves showing per cent true watts recorded
with varying power factor, normal voltage,
normal frequency, full load current
I – Run No 5 – Experimental
II – No 4 – Calculated

EUGENE DIETZGEN CO. CHICAGO-NEW YORK

ARMOUR
INSTITUTE OF TECHNOLOGY
LIBRARY.